DENTAL RADIOLOGY HANDBOOK

HOLLIDAY

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ROENTGEN

DENTAL RADIOLOGY HANDBOOK

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PREFACE

THIS book aims to present the essentials of dental radiology in a simple and compact form for ready reference and review. It should be of value also as an elementary text book in dental schools and should fill a long felt want in schools for dental hygienists. Students of the latter, who often have had no high school or college courses in physics, have had no comprehensive text dealing with the fundamental principles of x-ray physics.

It is not in the scope of this book to go into the interpretation of the various pathological conditions which are revealed by the x-rays, but rather to familiarize the reader with the basic principles necessary to the production of x-ray negatives which will be adequate for intelligent interpretation.

As the subject matter has been well developed previously and is generally available, the merit of this book rests in the assembling of material, its arrangement, the emphasis given, and the illustrations selected.

The time given by the instructor to different portions of the text will vary with the teaching facilities available, the requirements of state boards of examiners, as well as the special needs that may be felt. Thus where the students are required to have a knowl-

edge of elementary electricity a larger amount of time may be spent on the first chapters than where there is no such requirement.

The large number of illustrations is considered essential to make clear the text. Where it is not possible to conduct experiments before the class, the student is dependent very largely upon illustrations for comprehension of the text.

I wish to acknowledge the assistance of many friends in the fields of Education and Radiology with whom the teaching problems have been discussed, and of various publications from which ideas for illustrations were derived, particularly Dr. Ennis' work on Roentgenology and the publications of the Eastman Kodak Company and the Ritter Dental Manufacturing Company. Credit is also due to Mrs. Katharine Kingsbury for execution of the drawings.

HOUGHTON HOLLIDAY

New York City

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DENTAL RADIOLOGY HANDBOOK

CHAPTER I

LINEAGE

THE story of the descent of the x-rays and x-ray apparatus is a thrilling one, some knowledge of which will add materially to the satisfaction of those privileged to work with these rays. If we are content to push this or that button we are not worthy of professional rank. An attempt will be made here to trace very briefly this interesting history from the early days so that we may be able to follow the development down to the present. Many important steps will have to be left out and others will be treated but inadequately. However, it is hoped that an interest may be aroused which will cause the reader to seek for additional information.

In October, 1895, Professor Roentgen, like many other physicists, had taken up the study of cathode rays. The recent researches of Lenard and others had aroused a great deal of interest in these new rays, and all were anxious to know more about them. However, to understand what Roentgen was doing we must briefly review the work of his "Scientific Forefathers." We must go back to the discovery of magnetism and static electricity by the ancient Greeks.

Magnetism was first discovered in a certain iron ore and since this happened to be found first near Magnesia, Asia Minor, it came to be called magnet. The ancients noted certain properties that those natural magnets possessed. The ability to attract small particles of iron was concentrated at the ends or poles of the magnet, and if the magnet were allowed to swing freely, one end always pointed toward the North and the other toward the South. It was noticed that the north pointing end of one magnet would be repelled by the north pointing end of another. In other words, like poles repelled each other, but unlike poles attracted each other. It was discovered that the presence and direction of this magnetic force could be demonstrated by sprinkling iron filings on a paper held over the magnet. It was also found that the magnetic property could be imparted to pieces of iron and steel. These later are called artificial magnets.

It was also discovered very early that friction caused amber to attract small light particles to it. Other substances were found to possess this property, also, but there was a difference noted in the charges produced on different substances. Some substances always acquired a charge like the charge produced on glass when rubbed with silk. Such charges were called positive and all others were called negative. Similar to the reaction between magnet poles, like charges of this friction or static electricity were found to repel each other and unlike charges attracted each other.

No real advance in the study of electricity was made, however, until the time of William Gilbert (1540–1603). He repeated and extended the work of the ancients in the field of magnetism and static electricity and his writings formed the real scientific foundation for all subsequent investigation in this field. We will restrict ourselves to the work of his followers which ultimately led to the development of the high voltage apparatus used by Roentgen.

Up to the time of Galvani (1737–1798) all electrical phenomena came from this static electricity, but Galvani observed the twitching of a frog's leg suspended by a copper hook to an iron rail and discovered an entirely new electricity. He was mistaken about its source, thinking that the tissue itself was the source of the current.

Volta took up Galvani's experiments and concluded that the current did not originate in the animal tissue but in the metals themselves. From his experiments came the voltaic cell, which was to revolutionize the sciences of physics and chemistry. With this new electricity (current electricity) new apparatus was developed which was to carry us on toward the discovery of the x-rays.

Oerstedt (1777–1851) carried on experiments which were to link up magnetism and electricity. He was observing the behavior of the compass needle during a storm when he happened accidentally to close the circuit to a voltaic cell. The storm had produced no

effect on the needle, but the instant that the electricity passed through the wires leading from the cell, the needle was definitely deflected. Further experiments revealed the fact that the direction of the deflection depended upon the direction of the flow of current in the wire and as to whether the compass was placed above or below the wire. Thus a magnetic field was found to be present not only around a magnet but about any wire carrying a current of electricity. Ampere went further with Oerstedt's experiments and discovered that the attraction and repulsion between the poles of magnets was also present between two wires carrying current.

We must jump over a great deal of experimental work to a consideration of the next great advance made by Faraday (1791–1867). He was greatly interested in the correlation between electric and magnetic forces. He reasoned that since a current in a wire influenced a compass (or magnet) that the magnetic field of the magnet must produce electric forces in the conducting wires. In 1831 he discovered that when a current is started or stopped in an electric circuit, there is a momentary current in any closed circuit in the immediate neighborhood. The circuit in which the current is started or stopped is called the primary circuit and the circuit in which the momentary current circulates is called the secondary circuit. The currents generated in this secondary circuit are called induced currents. The same phenomena was demonstrated

when a magnet was moved inside a coil of copper wire. The induced current lasted only while the conductor was cutting across the magnetic lines of force and the voltage of the induced current depended upon the rate at which the magnetic field changed.

Practically all of our present day application of electricity depends upon this discovery of Faraday and Henry. Henry was an American scientist who was carrying on the same type of experimental work as Faraday and apparently unknown to each other they made this discovery at about the same time. Delay in the publication of Henry's work, however, prevents him from sharing equal fame with Faraday. Though this discovery has led to the widespread use of electricity, we are particularly interested in it because it made possible the production of the high voltage current which was essential to Roentgen's work.

Having these new high voltage induced currents, scientists began to study their characteristics. Sparks were observed to jump between the terminals of a high voltage machine. This disruptive discharge was observed to have certain characteristics. The distance through which the spark would jump from certain sized terminals and under standard conditions came to be used as a rough measure of the voltage of the current. The physicists then undertook to study the behavior of these discharges in tubes from which part of the air had been removed. The study of electric discharges was retarded, however, because of inefficient

air pumps and vacuum tubes. In 1865 Sprengel developed the mercury air pump which made it possible to produce a relatively high vacuum. And Geissler provided an improved tube. As the pressure was reduced in these tubes, colorful effects were noted. Around the cathode or negative terminal within the tube there was a luminous area. Beyond this there was a dark space and near the anode or positive terminal there was a peach blossom glow. As the vacuum was increased, the dark space became larger until it occupied the entire tube. At this stage the glass itself would glow or fluoresce. It was found that this fluorescence was due to minute negative charges (electrons) which were given off from the cathode and traveled across the tube at terrific speed bombarding the glass. These streams of electrons were called cathode rays and much interest was directed toward a study of their characteristics. Though they were invisible their effects could be studied with fluorescing substances.

This was about the state of affairs in the construction of high tension apparatus and concerning the knowledge of discharges of electricity through rarefied gases when Wilhelm Conrad Roentgen started to make his experiments on these problems in October, 1895. Roentgen's discovery was to be the glorious finale to the researches which had been going on for years. The apparatus which he used represented the labors of many investigators over a period of three hundred

years. The most prominent of these were Gilbert, von Guericke, Abbe, Nollet, Galvani, Volta, Ampere, Ohm, Faraday, Henry, Hittorf, Crookes, Hertz, and Lenard. These and many others contributed some part to the development of the knowledge of the properties of electricity, to the methods of its production, to the production of high tension currents, and to a study of the effects produced by these currents in highly evacuated tubes.

Roentgen was Professor of Physics at the University of Wurzburg. The brilliant work of Hertz and Lenard and others had revealed many new and interesting things and Roentgen like many others undertook to make a further study of these peculiar rays. On November 8th he was working with a vacuum discharge tube in a darkened room. Since he was looking for light rays beyond the visible spectrum, he had covered the tube completely with black paper. When the high tension current was turned on, he noticed that a barium platinocyanide fluorescent screen lying on a table a few feet away glowed. The covering on the tube made it impossible that this fluorescence was due to ordinary or ultraviolet light, and he reasoned that there must be some strange radiation coming from the tube. He found that objects interposed between the tube and the screen caused shadows to appear on the screen. Since this peculiar radiation caused the screen to glow, he decided to see if it would also affect the photographic emulsion, and proceeded to

take those first radiographs which are now so familiar to all. So Roentgen discovered a new invisible ray capable of penetrating material which was opaque to ordinary light and which affected the photographic emulsion as did ordinary light.

The news spread quickly and even before Roentgen had made a public report feverish activity was evident in laboratories all over the world as scientists endeavored to duplicate Roentgen's findings. The distinction of producing the first radiogram in America probably belongs to Professor Pupin of Columbia University, who had the equipment necessary and was working on the same problem at the time word was received of Roentgen's discovery. Edison also repeated Roentgen's work at about the same time as Pupin, and a few weeks later many others set up the apparatus and not only experimented with the rays but actually produced radiograms for physicians who sent patients beseeching help in detecting disease.

Although these x-rays aroused universal interest, they did not at once win universal approval. Along with the enthusiasm there was some opposition and many ridiculing cartoons and wild tales.

These pioneers in radiology enjoyed the thrill of the pioneer but they also put up with the handicaps of the pioneer, and there were to be x-ray martyrs. The early equipment was cumbersome and unreliable. It consisted of some means of producing a high voltage current, a vacuum tube, the most satisfactory type

available in the early days being the Hittorf-Crookes tube. It was also necessary to have a support for the tube, a fluoroscope, and the photographic plates.

The exposures were long, varying from a number of minutes to an hour or more. Very early in Roentgen experimentation, it was observed that certain undesirable results followed these excessive exposures to the x-rays. Loss of hair was first reported. One of Edison's assistants became the first known victim, dying from what was called x-ray cancer. In the light of these and other tragic results, every effort was made to reduce the exposure time. The first great drop in exposure time came as a result of Professor Pupin's experimenting with a new fluorescent material sent to him by Edison. By placing screens made of calcium tungstate next to the plate during exposure to the x-rays, he was able to reduce the exposure from minutes to seconds. Later improvement in the emulsion and the shift from glass to celluloid as a base for the emulsion has still further reduced the time of exposure and improved the results. Along with the improvement in this direction there was a steady improvement in the apparatus itself.

Static machines had been in use by physicians for therapeutic work, and by lightning rod dealers to demonstrate the efficacy of lightning rods. Hence many of the early x-ray machines used these static machines to furnish the high voltage. The energy output was insufficient, however, and as a result the time

of exposure varied from a few minutes to an hour or more, and it was frequently impossible to hold the patient still for that length of time.

The induction coil provided an increased energy over that obtainable from the static machines and soon replaced the former. The introduction of the transformer in 1907 resulted in a marked advance. Great energy was available and was more easily regulated. In fact more energy was available than the tubes of that day were able to carry and improvement in the tubes soon followed. The method of producing the x-ray remained the same, however, namely, by imparting a high velocity to electrons by means of the high tension current and then suddenly stopping them by collision with a solid body, the target. In the early tubes the vacuum had to be such that the molecules of remaining gas were broken up into positive and negative charges. The positive charges were attracted to the cathode and dislodged electrons from the metal. These electrons were then driven across the tube toward the anode terminal. In the early tubes the glass walls of the tube served to stop the cathode rays. Soon a high fusing metal target was used to stop rays. Then the cathode was made concave to focus the cathode rays on a small area of this metal target and so increasing the sharpness of the resulting shadows. Operating these early tubes changed the gas pressure and since the volume of the x-rays depended upon the degree of vacuum, much annoy-

ance was experienced in trying to maintain a constant degree of vacuum. Various devices were inserted in the tube in an effort to regulate the pressure or, as it was called, the gas. Most of the trouble experienced with gas tubes was due to the presence of this gas and yet, if it were entirely removed, some other means would have to be provided to get electrons out of the cathode.

In his work on the incandescent lamp Edison had shown that in the vacuum of the lamp a current could be made to flow from the hot filament to the anode. On the basis of Edison's observation and additional work of others which proved that electrons were emitted from hot metals, Coolidge made an x-ray tube inserting a hot tungsten filament. In this tube the volume of electrons and hence of x-rays was dependent upon the temperature of this tungsten filament, and the temperature could be accurately controlled by regulating the amount of an independent current which passed through it.

The transformer always delivers alternating current and since these hot cathode tubes would permit the passage of current in only one direction, means had to be provided for rectifying the high voltage current before it reached the tube. This was accomplished by various mechanical devices and later by the use of vacuum tubes, similar to x-ray tubes, inserted in the circuit.

For work not requiring a tremendous output of en-

ergy, Coolidge constructed a self-rectifying or radiator type of tube. This operates on the principle that so long as the anode is cooler than the cathode the tube will suppress one phase of the alternating current and use the other traveling in the desired direction.

Numerous other variations have been made in tubes which have made the apparatus more flexible, smaller, and more simple to operate. Some tubes emit the x-rays through the cathode, some are immersed in oil with the transformer, for cooling and for safety, and others are water cooled. There are tubes which operate on ten thousand volts or less and others that operate on seven hundred thousand volts or more.

These ten thousand volt machines are used for treating skin conditions and for x-raying insects and microscopic sections. The more powerful machines are used for deep therapy and for testing castings, welded joints, etc. And in between come the great range of diagnostic apparatus including the dental units which are adapted to our limited needs and limited floor space. All of these, however, are descendants of that apparatus which Roentgen used in his physics laboratory back in 1895.

CHAPTER II

MAGNETISM

1. **Natural Magnets.** Certain iron ores, such as magnetite (Fe_3O_4), possess the property of attracting to themselves small pieces of iron. The ancient Greeks first made this discovery near Magnesia, a city in Asia Minor. Hence, this iron ore came to be known as magnet or magnetite. This ore has since been found in various parts of the world. It came to be called also lodestone (leading stone) when its directional properties were used by the early navigators. We now use a magnetized needle for this purpose and call it a compass.

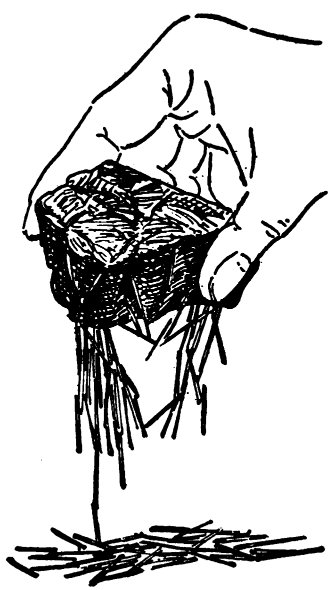

FIG. 1. A Natural Magnet.

2. **Magnetic Substances.** Many substances are influenced by magnetism to a slight degree, but for practical purposes iron is the only magnetic substance.

3. Artificial Magnets. When pieces of iron or steel are rubbed with a natural magnet, they acquire this power of attracting and holding bits of iron, and the

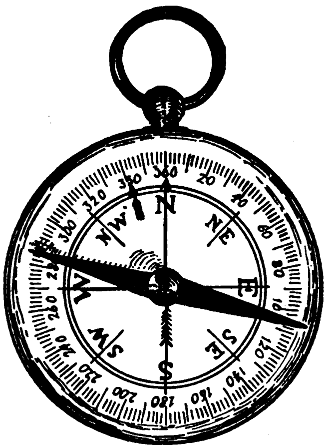

FIG. 2. Compass.

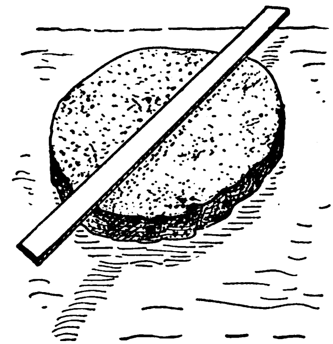

FIG. 3. An Artificial Magnet Floating.

natural magnet does not lose any of this property. This piece of iron or steel may be used to stroke another piece of iron or steel. This second piece acquires the magnetic property, and the first one suffers no loss. Artificial magnets are pieces of hardened steel that have been made magnetic by the application of another magnet. Artificial magnets are usually in the form of a bar or horseshoe.

4. Magnetic Poles. If we place a sheet of paper over a bar magnet and sprinkle iron filings on it, the filings will cling more thickly toward the ends while only a few will remain in the middle of the bar. These ends

or points of greatest attraction are called the poles.

If we float a magnet on a piece of board or suspend it so that it is free to swing in a horizontal plane, it will always come to rest in a north and south position. The end of such a freely supported magnet which points north is called the north pole, and the other end the south pole.

The magnetic needle or compass may be used to detect polarity, but since a piece of soft iron will attract either pole of the compass, repulsion is the only sure test. The north pole of the compass will be repelled by the north pole of a magnet.

5. **Mutual Action of Magnetic Poles.** If two bar magnets, free to swing in a horizontal plane, have the north poles of each brought together, they will be found to repel each other. Similarly, the two south poles will repel each other. However, if the south pole of one magnet is brought near the north pole of the other, they will be seen to attract each other.

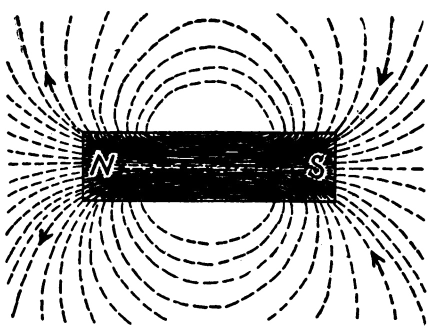

FIG. 4. Magnetic Lines of Force About an Artificial Magnet.

Laws of Magnetic Action: Like magnetic poles repel each other and unlike magnetic poles attract each other.

6. **Magnetic Field and Lines of Force.** A magnetic

field is the space around a magnet in which it exerts its influence. If a magnetic compass is placed anywhere in this space, it points along a tangent to a line of force. Iron filings sprinkled on a paper covering a magnet become small magnets, or compasses, by induction, and take positions along the lines through which the force acts.

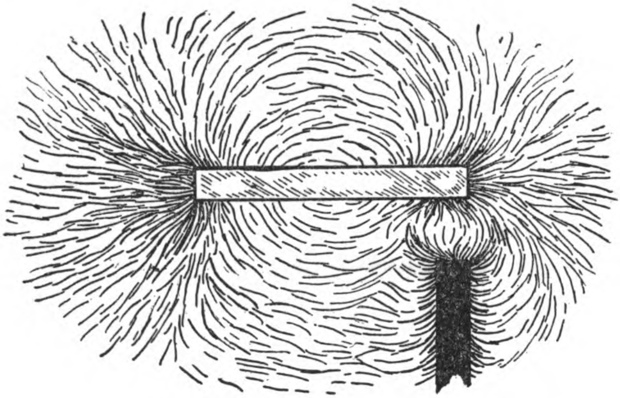

FIG. 5. Illustrating Permeability of Soft Iron.

7. **Mutual Action of Magnetic Lines of Force.** Iron filings sprinkled over a sheet of paper on a bar magnet become magnetized by induction and act like small compass needles. On tapping the paper lightly, the filings arrange themselves along curves extending from one end of the magnet to the other.

8. **Permeability and Retentivity.** When iron is placed in a magnetic field, it forms a ready path for the lines of force, drawing them within itself. Soft iron

possesses this property to a high degree, that is it readily sets up magnetic lines of force within itself. The retentivity of a substance is the relative ability of a substance to hold its magnetism. While soft iron is permeable to a high degree, it is low in retentivity, and steel is low in permeability but high in retentivity.

9. **Nature of Magnetism.**

A. No matter how many parts a magnet is broken into, each part is itself a magnet.

B. Heating, jarring, hammering, or twisting reduces magnetism.

C. A test tube of iron filings can be magnetized by stroking it with a magnet, but when the filings are shaken up, the magnetism disappears.

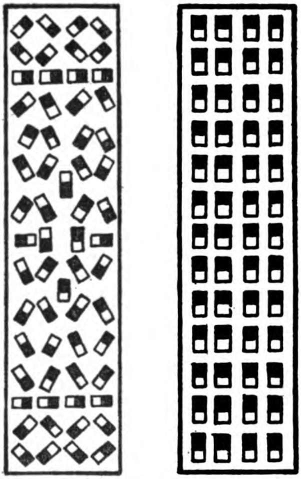

FIG. 6. Illustrating Theory of Magnetization.

10. **Molecular Theory of Magnetism.**

A. Each molecule of a magnetic substance is a magnet whether the substance itself is magnetized or not.

B. When the substance is magnetized, its molecules are arranged in a definite order, and the poles of the tiny magnets attract each other.

C. When a substance is magnetized, its molecules are arranged so that their north poles all point in the same direction.

This present theory was suggested by the fact that if we break a magnet, each part becomes a magnet, and this continues no matter how many times the magnet is broken. A glass tube of iron filings can be magnetized, but when shaken, it loses its magnetism. Hence, every molecule of a bar of iron is regarded as a tiny permanent magnet. Ordinarily, there is no order to the arrangement of these molecular magnets, and there is no magnetic effect apparent outside the bar. However, when these molecular magnets are lined up, north pole of one to the south pole of the next, the cumulative effect is evident at either end of the bar, and the bar is said to be magnetized.

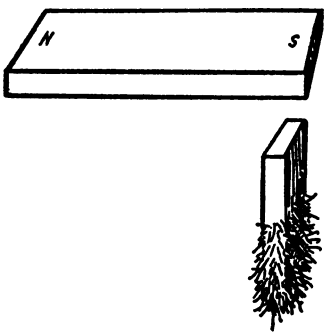

FIG. 7. Magnetization by Induction.

11. **Means of Producing Magnetism.**

A. By contact. When a piece of steel is stroked a number of times in the same direction with the same pole of a magnet, it becomes a magnet.

B. By induction. When a piece of iron or steel is placed near a pole of a magnet, it becomes magnetized, and the process is known as magnetic induction. A small piece of iron may be permitted to adhere to one end of a bar magnet. A second piece will adhere to the first, and so on. The number of pieces retained depends

on the strength of the magnet. Now if we remove the magnet, the pieces will fall apart. They held together because they were temporary magnets.

C. By electricity. If several turns of insulated wire are wound about a piece of iron and an electric current is allowed to flow through the wire, the iron becomes a magnet. If soft iron is used, the magnetism soon disappears, but if steel is used, we have a permanent magnet.

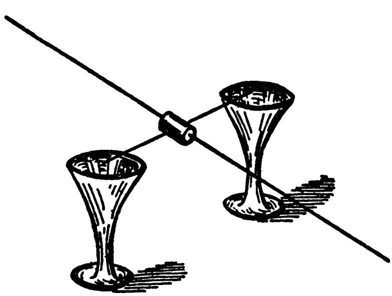

FIG. 8. Inclination or Dip of a Magnetic Needle.

12. Terrestrial Magnetism. The behavior of the magnetic compass on the earth's surface resulted in the conclusion that the earth is a huge magnet. Iron objects, such as boilers, stoves, pipe, etc., became magnetized by induction with the lower end a north pole.

These magnetic poles are not identical with the geographical poles. One is in North America near Hudson Bay, and the other nearly opposite in the antarctic region. Accordingly, the compass does not point true north and south. The angle between the direction of the magnetic needle and the meridian at any place is the magnetic *declination* for that place.

If a compass needle is perfectly balanced so that it can swing up and down as well as sideway, its north-

seeking pole will dip north of the equator, and the south-seeking pole will dip south of the equator. Near the magnetic equator there is no dip. The inclination or *dip* of a needle is the angle its axis makes with a horizontal plane.

Questions.

1. Can a magnet have just one pole?
2. If the north-seeking pole of a magnet is attracted to the north, what kind of a magnetic pole is in the north?
3. Do the magnetic poles of the earth and the geographical poles coincide?
4. If the lower end of a radiator is found to repel the north-seeking pole of a compass, what pole of a compass would be attracted by the top of a stove in South America?
5. Would a compass placed in a "tin" can be affected by a magnet brought near the outside of the can?
6. Will a magnet attract an aluminum pan?
7. Are iron objects magnetized by induction or contact when terrestrial magnetism passes through them for a period of time?
8. What do we think happens to the molecules in a steel bar as it becomes magnetized?
9. Why does the compass not point true north?
10. Give two methods of magnetizing a piece of steel.

CHAPTER III

ELECTROSTATICS

1. **Electricity Produced by Friction.** That branch of physics which deals with electrified bodies and the force actions between them is called electrostatics. The ancient Greeks knew that rubbing amber with wool gave amber the property of attracting small pieces of pith, paper, and other very light particles. Not until about 1600, however, was any further advance made. Experimenters then discovered that a large number of substances became electrified when rubbed with silk, cat's fur, etc., while other substances did not.

2. **Electrified Bodies.** Substances which have acquired this property are said to be electrified or to have an electric charge. Amber with other bright substances was called electron by the Greeks. Hence, this phenomenon came to have the term electric.

3. **Positive and Negative Electricity.** It was found in 1733 that there were two kinds of electrification. Rubbing glass with silk, for instance, produced a charge different from that produced by rubbing rubber with wool. Two objects similarly charged repelled each other while a glass rod carrying a charge is attracted by a rod of sealing wax in which there is a

charge produced by friction with flannel. To distinguish one from the other, scientists have called charges similar to the charge produced by rubbing glass with silk, positive charges, and charges similar to that produced by rubbing rubber with wool, negative charges.

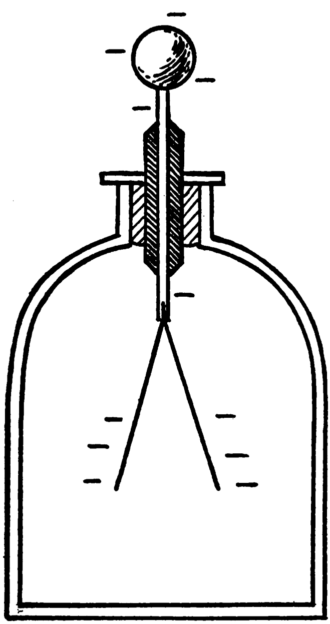

FIG. 9. A Gold Leaf Electroscope.

4. **Laws of Electric Action.**

A. Like charges repel.

B. Unlike charges attract.

5. **Equality of Charges.** When electricity is produced by friction, the two substances rubbed together acquire equal and opposite charges. Hence, when glass is rubbed with silk, the silk acquires a negative charge equal to the positive charge on the glass.

6. **The Electroscope.** An electroscope is a device for detecting the presence of an electric charge and for determining the kind of electricity with which an electrified body is charged. One form of electroscope, known as the gold leaf electroscope, consists of two slender strips of gold foil suspended from a metal rod as represented in Figure 9. The instrument is usually mounted in a glass jar

to protect it from outside disturbances. The operation of the electroscope depends upon the fact that like charges repel.

If we rub a glass rod with silk and then bring the rod near the knob on the top of the electroscope, the gold leaves will diverge. On removing the glass rod the leaves collapse. Since the leaves do not remain repelled, no charge has been transferred to the electroscope from the rod. This temporary electrical condition set up in the electroscope is known as electrification by *induction.*

The electroscope may be charged by direct contact of the charged body and the knob on the electroscope. If this is done the electroscope acquires the same charge as the charged body. If the charge is too strong it may tear the gold leaves from the rod. To test the kind of electrification on a body having an unknown charge, first charge the electroscope with a slight charge of a known character. Then apply the body bearing the unknown charge. If it is the same as that already on the electroscope the leaves will diverge still further.

7. **Conductors and Insulators.** Some substances will conduct electricity readily while others will not. Those substances which readily transmit electricity we call conductors and those which do not transmit it readily we call insulators.

Kimball's *College Physics* classifies bodies according to their insulating powers as follows:

Insulators	*Poor Conductors*	*Good Conductors*
Amber	Dry Wood	All metals
Sulphur	Paper	Carbon
Fused Quartz	Alcohol	Graphite
Glass	Turpentine	Water solution of salt
Hard Rubber	Distilled Water	
Air and Gases		

8. **The Condenser.** The condenser is a device for increasing the capacity of a conductor without in-

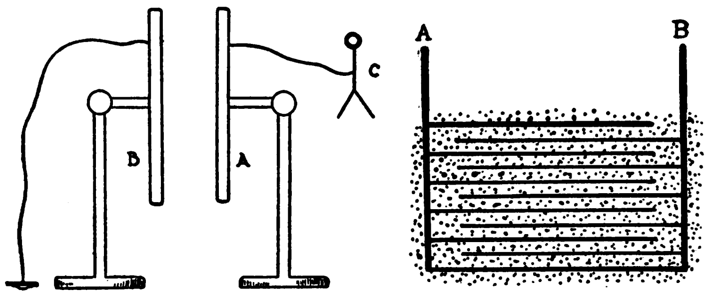

FIG. 10. Simple Condensers.

creasing its potential. The capacity depends upon the presence of other conductors in its immediate neighborhood. A condenser consists of two conductors, A and B, Fig. 10, separated by a layer of non-conducting material. Condensers are sometimes used to build up very high potential.

9. **The Atomic or Electron Theory.** According to this theory the nucleus of atoms is an aggregation of positive and negative electricity, with positive elec-

tricity predominating. The excess positive electricity is neutralized by electrons (negative electricity) revolving about the nucleus. These tiny particles of negative electricity are held in their various paths around the nucleus by the excess positive electricity at the nucleus. The whole atomic structure resembles somewhat our solar system.

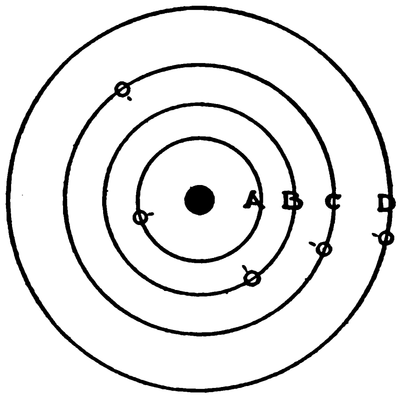

FIG. 11. Atomic Theory.

An unelectrified body is made up of equal amounts of positive and negative electricity.

When a body is positively charged, it contains more positive than negative electricity.

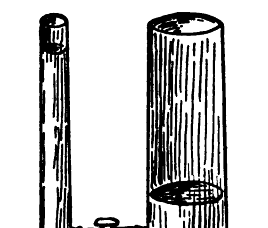
FIG. 12. Illustrating Potential Difference.

When a body is negatively charged, it contains more negative than positive electricity.

All effects of electricity are thought of as being due to free electrons (negative electricity) which in various ways become separated from atoms.

10. **Potential.** Electrical potential is that condition which determines the flow of electricity. To have a

flow of electricity, there must be a difference of potential. The difference in level which causes the flow of water is analogous to the difference in electrical potential which determines the flow of electricity.

11. **Electric Machines.** Following the discovery of the reaction between unlike and like charges, machines were devised to generate electrical charges by friction. These were called static machines. A spark could be made to jump a gap by bringing unlike electrodes close to each other.

A. The Electrophorus is a device for the rapid accumulation of charges and depends for its action upon the principle of induction. It consists essentially of a flat base of rubber, sealing wax, or other substance readily electrified by friction, A, and a disk, B, of conducting material provided with an insulating handle. It is used as follows: The base A is first rubbed with fur to charge it negatively. The disk B is now brought close to the base A and is charged by induction. The positive charge appears on the lower side of the disk, and the negative charge appears on the upper side. On touching the disk with the finger, electrons (negative charges) are repelled through the body to the earth, and the positive electricity is held on the disk by the negative charge on the base. Now remove the

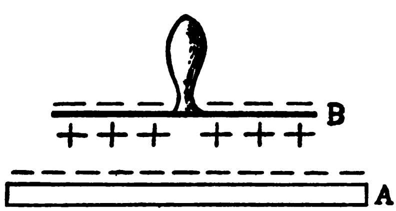

FIG. 13. Electrophorus.

finger, and then withdraw the disk. There remains upon the disk B a positive charge which may be carried upon the disk and used as desired.

Questions.

1. What was the first substance to be used to produce static electricity?
2. Positive electricity may be produced by what means?
3. Can positive and negative electricity be produced at the same time?
4. How does the electroscope show the kind of electricity with which an electrified body is charged?
5. What are the laws of electric action?
6. Is the same substance sometimes a conductor and at other times an insulator?
7. Make a diagram to illustrate the arrangement of the charges in the atomic theory.
8. Must there be a difference of potential in order to cause a flow of electricity?
9. What are electrons?
10. According to the atomic theory, when is a body considered as being positively charged?

CHAPTER IV

CURRENT ELECTRICITY

1. **Current Electricity** is electricity in motion whereas static electricity is electricity at rest, or under restraint. To have a current of electricity it is necessary to have (*a*) a difference of potential and (*b*) a complete electric circuit. In the case of charges of static electricity there may be a sudden flow of electricity caused by a difference in potential. If this difference of potential were maintained, there would be a continuous flow of current electricity. When two conductors between which there is a difference of potential are connected by a wire, a transfer of electricity takes place. Under these circumstances there is said to be an electric current in the wire.

2. **Galvani's Discovery.** In 1776 Galvani, an Italian Professor of Anatomy, was experimenting on the muscular contraction produced by electric discharges from a static machine. One day he observed that freshly prepared frog legs which he had clipped to copper hooks, twitched when he suspended them from an iron bar. He recognized the twitching as being identical to that produced by the static electricity, and concluded

that there was electricity within the tissue. He had discovered an entirely new electricity, but later work was to prove that he was mistaken in thinking that the tissue itself was the source of the current.

3. **The Voltaic Cell.** Volta took up Galvani's ex-

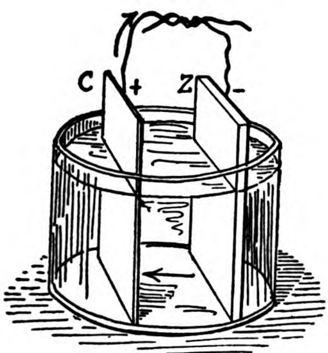

FIG. 14. Simple Voltaic Cell.

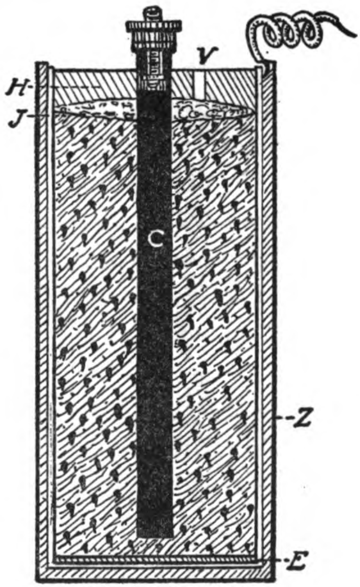

FIG. 15. Dry Cell.

periment and concluded that the current originated on the metals and not in the tissue. While investigating Galvani's discovery, Volta invented a chemical method of producing electricity. A dilute solution of sulphuric acid is placed in a glass jar. A strip of copper and one of zinc are placed in the solution. If the two

strips are connected outside the solution, there will be a flow of current from the copper to the zinc (the direction as per convention). Upon examining such a cell it will be found that there is a difference of potential between the copper and the zinc while they are in the solution. The copper is positively charged while the zinc is negatively charged. The pieces of copper and zinc are called electrodes, and the acid solution is called the electrolyte. Any dissimilar metals may be used, and there are many liquids that may be used as the electrolyte. However, the potential difference between the electrodes varies with the electrolyte.

4. **Cell Phenomena.**

A. Heat is developed all along the circuit.

B. The magnetic needle is affected at any point in the circuit.

C. Chemical action takes place between the electrode and the liquid.

The above phenomena are present only while the circuit is complete.

In the cell there is a continuous difference of potential due to the interaction of the electrodes and the acid which causes a continuous flow of current. The potential of a cell is also called its electromotive force, E.M.F. The practical unit of electromotive force is called a volt.

5. **Electrical Measurements.**

A. Resistance. Electrical resistance is the opposition which all conductors of electricity offer to the passage

of an electric current through them. The unit of resistance is the Ohm.

B. Current Strength is the quantity of electricity that passes a given point in a circuit in one second. The unit of current strength is the Ampere.

C. Electromotive Force. The driving force that causes an electric current to flow is called the electromotive force (E.M.F.). It is due to the difference in potential between the two points through which the current is flowing. The unit of electromotive force is the Volt.

D. Ohm's Law. The current strength in any circuit is directly proportional to the electromotive force, and inversely proportional to the resistance of the circuit.

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \quad \text{or} \quad I = \frac{E}{R}$$

E. Electric Power. Electric power is the energy expended by a given electric current in one second. The unit of electric power is the Watt. 1 watt = 1 ampere × 1 volt. A watt is the rate at which energy is expended by a current of one ampere in that portion of a circuit between the terminals of which there is a potential difference of 1 volt.

F. Energy Consumption. The energy consumed when electrical devices are used is measured in kilowatt-hours.

$$\text{Kilowatt-hours} = \frac{\text{Volts} \times \text{amperes} \times \text{hours}}{1000}$$

G. Laws of Electrical Resistance.

1. Resistance of a conductor is directly proportional to its length. The resistance of a wire fifty feet long would be half that of a piece of the same wire one hundred feet long.
2. The resistance of a conductor is inversely proportional to the area of its cross section.
3. The resistance of a conductor varies with changes in its temperature. The resistance of metallic conductors increases as the temperature increases.
4. The resistance varies with the material. The resistance of an iron wire is greater than a copper wire of the same size.

6. **Fall of Potential.** There is a difference in the potential between any two points on a conductor carrying a current. The voltage which is lost in sending a current through any part of an electrical circuit is called the fall in potential.

This fall of potential in any part of a circuit is directly proportional to the resistance of that part of the circuit.

The total fall of potential in a circuit is equal to the sum of the falls in different parts of the circuit.

7. **Series Circuits.** Electric circuits are made up of conductors (resistances) connected in series or in parallel.

When resistances are connected in series, the strength of the current is the same in every part of the circuit.

The total resistance of the circuit is equal to the sum of the separate resistances.

The total voltage of the circuit is equal to the sum of the voltages of the separate resistances.

Fig. 16. Series Circuit.

8. **Parallel or Divided Circuits.** When resistances are connected in parallel:

A. The total current strength in the circuit is equal to the sum of the current strength in the several resistances.

B. The voltage is the same for all resistances and is equal to the difference of potential between the two points with which the resistances are connected.

C. In parallel circuits the strength of the currents in

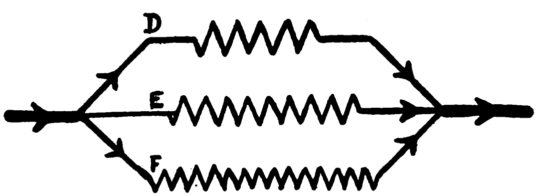

Fig. 17. Parallel Circuit.

the branches is inversely proportional to the resistances of the branches.

9. **Electromagnetism.** A wire carrying an electric current is surrounded by a magnetic field. In 1819

Oersted discovered that a wire connecting the electrodes of a voltaic cell when held *over* a compass

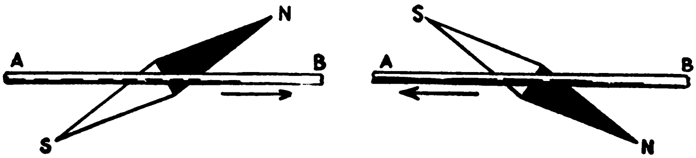

FIG. 18. Deflection of a Needle by a Current.

needle will cause the needle to assume a definite position. The properties of this magnetic field may also be studied with the aid of iron filings. When the wire is held so that the current flows from the south toward

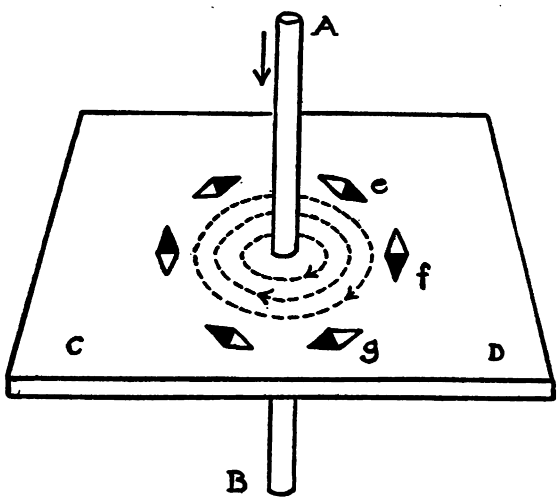

FIG. 19. Direction of Lines of Force About a Wire Carrying a Current

the north, the compass needle is deflected toward the west. Reversing the direction of the current causes the

needle to be deflected toward the east. Placing the wire carrying the current *beneath* the compass reverses the direction of the deflection in each case.

10. The Right-hand Rule for the Magnetic Field of a Current. The magnetic lines of force are concentric about a wire carrying a current, and from the deflection of a compass, as described above, the following rule has been evolved.

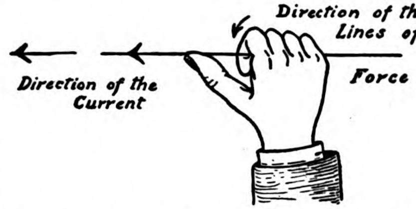

FIG. 20. Right Hand Rule for the Magnetic Field About a Conductor.

Grasp the wire with the right hand so that the thumb points in the direction in which the current is flowing. The fingers will then point in the direction in which the lines of force encircle the wire.

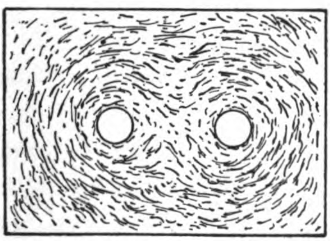

FIG. 21.
Same Direction

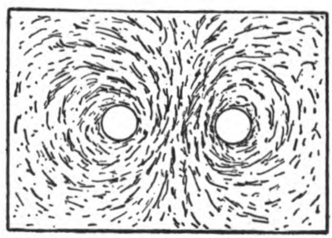

FIG. 22.
Opposite Directions

Magnetic Field About Parallel Currents.

11. Mutual Action of Two Currents. If the current is travelling in opposite directions through two paral-

lel wires, the magnetic lines of force will produce a stronger magnetic field between the wires. If the wires are free to move, they will be forced farther apart. If the current is passing in the same direction, the wires will tend to approach each other.

These facts may be summarized as follows:

1. Parallel currents flowing in the same direction attract.
2. Parallel currents flowing in opposite directions repel.
3. Currents making an angle with each other tend to become parallel and flow in the same direction.

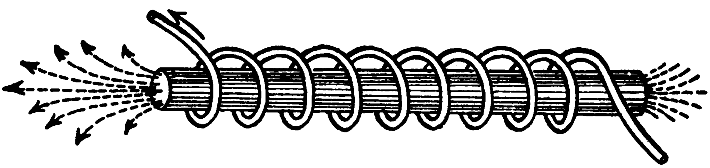

FIG. 23. The Electromagnet.

12. The Electromagnet. An electromagnet consists of a coil of insulated wire wound around a soft iron core. When an electric current flows through the wire, a magnetic field is produced. The strength of the electromagnet is greatly increased by the iron core because of its permeability.

13. Polarity of an Electromagnet. Grasp the coil with the right hand so that the fingers point in the same direction in which the current is flowing. The thumb will point to the north pole.

14. Strength of an Electromagnet. The strength of an electromagnet is directly proportional to:

A. The number of turns of wire. The greater the number of turns, the stronger the magnet.

B. The strength of the current flowing in the coil.

C. The permeability of the iron core.

15. Uses of Electromagnets. Electromagnets are used:

A. For loading pieces of iron or objects made of iron on cars, boats, etc.

B. In numerous electrical devices, such as the electric bell, telegraph, motor, dynamo, telephone induction coil, and the transformer.

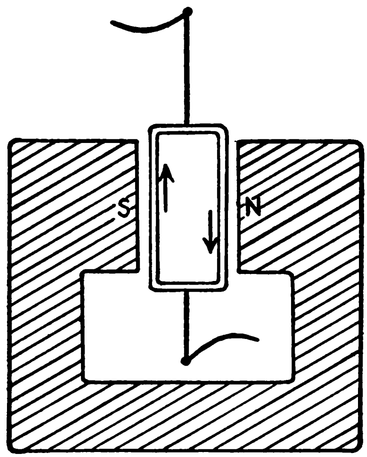

Fig. 24. A simple Galvanometer.

16. The Galvanometer. The galvanometer is an instrument for detecting the presence, strength, and direction of an electric current. It depends upon the magnetic effects of a current. Between the poles of a strong permanent horseshoe magnet swings a coil of fine wire, so suspended that the current is led into the coil by a fine suspending wire and out by a wire running to the base. The reaction of the magnetic fields, one from the permanent magnet and the other produced in the suspended coil, causes the rotation of the

latter. The extent and direction of the rotation is noted on a scale. A spring controls the movement of the suspended coil and causes it to return to the starting point when the current is shut off.

17. **The Ammeter.** The ammeter is designed to measure electric currents in amperes. It consists of a galvanometer with a low resistance shunt across the terminals of the coil to carry the main current so that putting the ammeter into the circuit will not change the current to be measured. A dial graduated to read in amperes gives the rotation of the suspended coil. Ammeters are always connected in series with the device whose current flow is to be measured.

18. **The Voltmeter.** The voltmeter is an instrument designed to measure the difference in potential between two points in an electrical circuit. It consists of a galvanometer protected by a high resistance coil in series with it. A graduated dial records the potential difference in volts. Voltmeters are always connected in parallel with some portion of the circuit whose fall of potential is to be measured.

Questions.

1. What two conditions must exist before we can have an electric current?
2. Upon what does the action of the Voltaic cell depend?
3. Do all conductors offer resistance to the flow of electricity?
4. What is the unit of resistance? of current strength? of potential? of electric power? of energy consumption?

5. State Ohm's Law.
6. Is the resistance in a small wire greater or less than that in a larger wire?
7. In a divided circuit the amperage bears what relationship to the resistance?
8. State the right hand rule for the magnetic field about a conductor.
9. What is the function of the core in an electromagnet?
10. Describe a simple d'Arsonval galvanometer.

Chapter V

ELECTROMAGNETIC INDUCTION

1. Induced Currents. Electromagnetic induction is a method of producing an electric current by the relative motion of a coil of wire and a magnetic field. It was discovered by an English scientist, Michael Faraday, in 1831 that whenever a current is started or

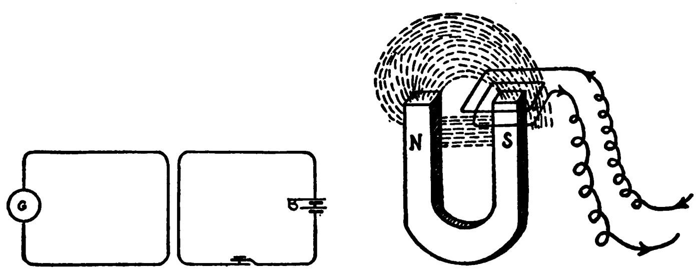

Fig. 25. Electromagnetic Induction.

stopped in an electric circuit, there is a momentary current in any other closed circuit in its immediate neighborhood. The circuit in which the current is started or stopped is called the primary circuit, and the circuit in which the momentary current circulated is called the secondary circuit. The momentary currents generated in this secondary circuit are called induced currents.

Whenever a conductor is moved in a magnetic field, whether that magnetic field be produced by an electric or a permanent magnet, a current is generated in the conductor. This current lasts only while the conductor is cutting across the magnetic lines of force, and the induced electromotive force depends upon the rate at which the magnetic field changes.

2. **Laws of Induced Currents.**

A. Whenever the number of magnetic lines of force passing through, or cut by, a coil of wire is changed, a current is induced in the coil.

B. The induced electromotive force is directly proportional to the rate at which the lines of force are cut.

3. **Fleming's Rule.** When the direction of the magnetic lines of force and the motion of the conductor are known, the direction of the induced E.M.F. may be determined by the following rule. Extend the thumb, forefinger, and middle finger of the right hand so that they form right angles with each other. If the thumb points in the direction of motion of the conductor, and the forefinger in the direction of the magnetic field, the middle finger will point in the direction taken by the induced current.

The E.M.F. is generated in the secondary in accordance with the following laws:

A. A momentary current in the opposite direction is induced in the secondary by the approach, the starting, or the strengthening of a current in the primary.

B. A momentary current in the same direction is in-

duced in the secondary by the receding, the stopping, or weakening of a current in the primary. The primary coil becomes a magnet when carrying an electric current and acts toward the secondary coil as if it were a magnet.

C. The induced E.M.F. at any instant is equal to the

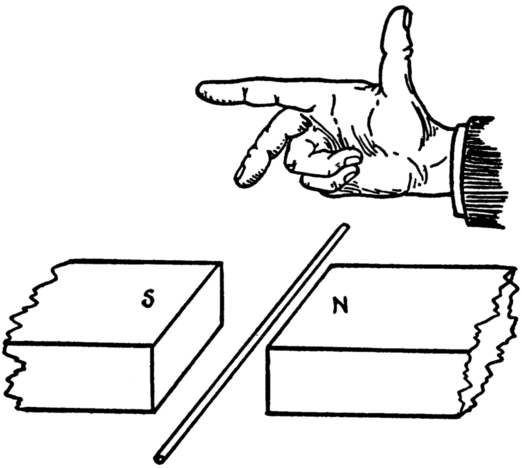

FIG. 26. Fleming's Rule.

rate of increase or decrease of the lines of force linked to the circuit.

4. **Self Induction.** A current passing through a coil of wire sets up a magnetic field which acts not only on adjacent circuits but also on its own circuit, and produces what is sometimes called a back E.M.F. This is produced only at the starting or stopping or changing of the magnitude of the current. Since this back

E.M.F. is developed in the coil in which the current which produces the changing magnetic field about the coil is flowing, it is called self-induced. In accordance with our laws regarding the behavior of induced currents, this self-induced E.M.F. is in such a direction as to oppose the current from the main (or battery) when the current is increasing or being started, and when the current is decreasing or is being stopped, it will flow in such a direction as to tend to maintain the current from the main.

5. **The Induction Coil.** The induction coil is a device which is used for developing high electromotive forces by utilizing the principle of electromagnetic induction. A high voltage current can be produced from a low voltage *direct* current.

A. The essential features of the induction coil are a core, which is composed of a bundle of soft iron rods, a few turns of heavy insulated copper wire which is known as the primary coil or circuit, and a secondary coil consisting of a great number of turns of fine insulated copper wire, an automatic interrupter and a condenser. The purpose of the core is to strengthen the magnetic field. The primary coil produces the magnetic field, and the secondary coil cuts across the magnetic lines of force, and thereby produces an induced E.M.F. in the secondary circuit.

B. Action of the Induction Coil. The current flows through the primary coil. This magnetizes the iron core which then attracts the soft iron head on the in-

terrupter. The circuit is thus broken, and the core is demagnetized. The spring brings the head of the interrupter in contact with the circuit again. The circuit is thus closed again, and the process is repeated. At each make and break of the current in the primary coil, an electromotive force is induced in the secondary.

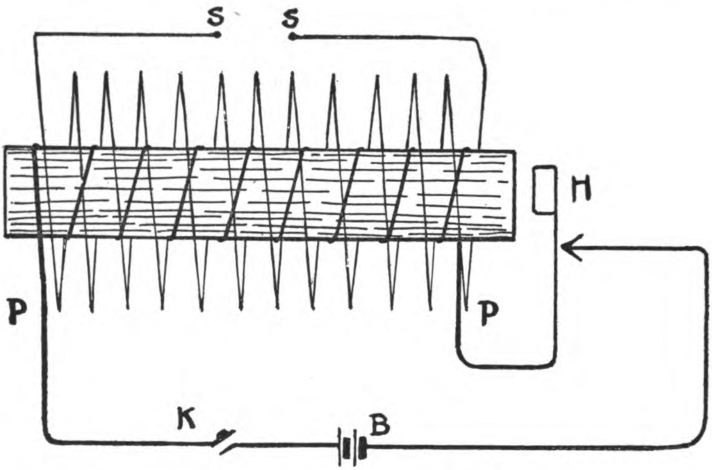

FIG. 27. The Induction Coil.

C. Uses of the Induction Coil. The induction coil is used to develop high voltage currents for x-ray tubes, for ignition in gas engines, for wireless, and in certain types of therapy.

6. **The Transformer.** The purpose of the transformer is to step up or down the voltage of an *alternating* current. Since the induction of electromotive forces depends upon the starting and stopping of the current

in the primary, it is possible by means of the alternating current to transfer electric energy from one circuit to another with which it has no metallic contact by making use of the principle of electromagnetic induction.

A. The chief parts to a transformer are: two coils of insulated wire wound around a soft iron frame. One of

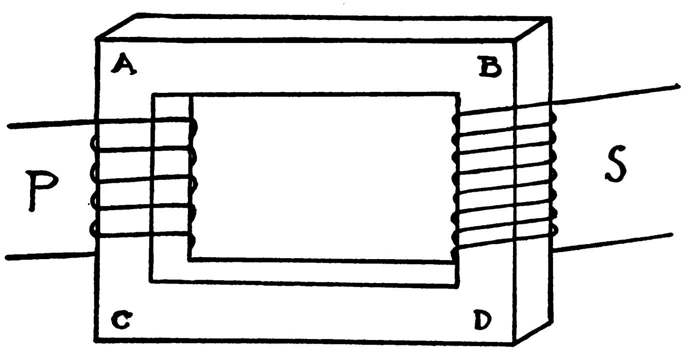

FIG. 28. The Transformer.

these coils is the primary, and the other is the secondary.

When the number of turns of wire in the secondary coil exceeds the number of turns in the primary coil, the transformer is known as a step-up transformer.

When the number of turns in the secondary is less than the number of turns in the primary, the transformer is a step-down transformer.

The voltage in the secondary coil is roughly pro-

portional to the ratio of the number of turns in the secondary to the number of turns in the primary, multiplied by the voltage in the primary.

$$\frac{\text{Voltage in primary}}{\text{Voltage in secondary}} = \frac{\text{Number of turns on primary}}{\text{Number of turns on secondary}}$$

If there are five turns on the primary and five hundred on the secondary, the voltage in the secondary would be approximately 100 times what it was in the primary. To reduce a 20,000 volt current to a ten volt current there would be 2000 turns on the primary for every turn of the secondary.

B. Transformers are used for developing high voltage currents to operate x-ray tubes, for radio sets, for stepping-up a current for distant transmission from a power station, and for stepping it down to a voltage safe to use in houses and factories. In the distribution of electricity throughout a city the generator produces current of a low voltage which passes through the primary coil of a transformer and is stepped up to 2200 volts before it leaves the power house. This current is sent out over the city to points where it is to be used. At these points there are step-down transformers which step the voltage down to 110 or 220 volts, the usual voltage for household and commercial purposes. The reason for sending a high voltage and a comparatively small current over transmission lines is that less power is lost in heating the wire. The reason for using a larger current at a low voltage for homes and commercial

purposes is the fact that it can be more readily insulated and is less dangerous.

C. Auto-transformer. In x-ray apparatus the current passing into the step-up transformer is controlled by an auto-transformer. This device consists of a soft iron core surrounded by coils of wire of comparatively low resistance. Wires lead off from different points of the

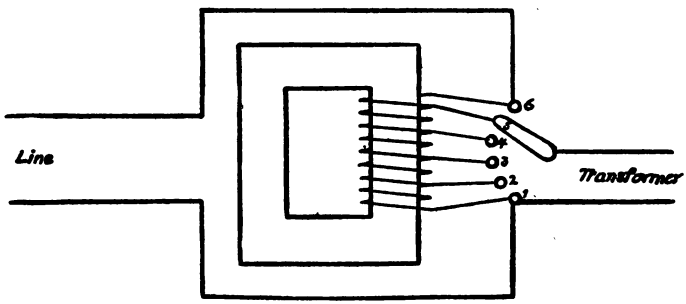

FIG. 29. Auto-Transformer.

coil in such a way that the current from the mains can be fed through a larger or smaller number of turns on its way to the high voltage transformer. The soft iron core causes the development of a back electromotive force due to self induction. In this way the current can be increased or decreased to compensate for fluctuations in the line.

7. The Dynamo and the Motor.

A. The principle of the Dynamo. A dynamo transforms mechanical energy into electrical energy. It depends for its action upon the principle of electromagnetic induction. It consists of several connected coils

of wire wound around an iron core which revolves within the field of a powerful electromagnet. The revolving coils continually cut magnetic lines of force and an induced E.M.F. is therefore being constantly produced in some portion of the coils.

B. The essential Parts of a Dynamo.

1. A *magnetic field* produced by permanent or electromagnets.

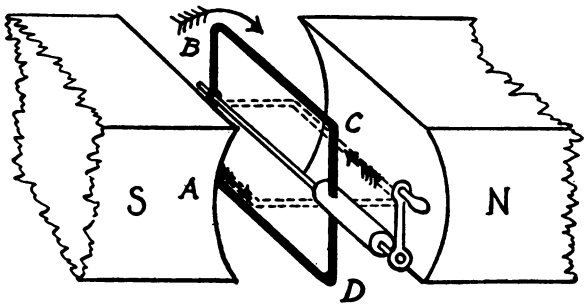

FIG. 30. Illustrating the Principle of the Dynamo.

2. An *armature* which is a coil of copper wire wound around a soft iron core and so arranged that it can rotate between the poles of the magnetic field.

3. Means for collecting the current from the armature: slip rings and brushes.

C. Operation of the Dynamo. If a coil of wire of one turn is arranged so that it can be rotated between the poles of a strong magnet, a current will be induced in the wire because of the changing lines of force about the wire. As the coil in the diagram is turned in a

clockwise direction, one side of the loop moves down as the opposite side moves up. According to Fleming's rule the induced current would flow in the direction indicated during the first half turn and in the opposite direction during the second half turn. The induced E.M.F. reaches its maximum when the loop is horizontal since in that position the lines of force are being cut more rapidly. Accordingly, during the first half-turn the E.M.F. starts at zero, reaches a maximum, and drops again to zero. In the second half-turn the procedure would be repeated but in the opposite direction. A large dynamo has many turns of wire so that the same magnetic lines of force cut many loops of wire. The quantity of current induced depends upon the rate at which the coils are revolved in the magnetic field and upon the strength of the magnetic field.

8. **The Electric Motor.** The electric motor is a device for transforming electrical energy into mechanical energy. It is essentially a dynamo. By connecting a source of electrical power to the coils which have been generating electricity we make another magnetic field. We have one from the permanent magnets and the other from the electrical current. We have observed that when magnetic lines of force oppose each other, we have a weak magnetic field, and when the magnetic lines of force run parallel, we have a strong field. If the loops of wire are free to rotate, the strong field on one side and the weak field on the other side of the loop will tend to make the coil rotate.

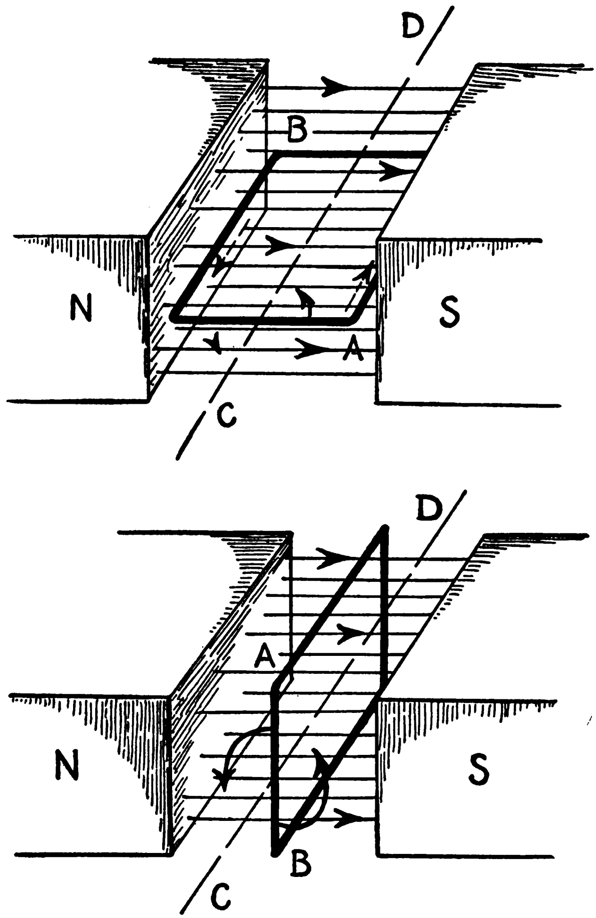

FIG. 31. Illustrating the Principle of the Motor.

9. X-ray Current-Voltage Requirements. Modern dental x-ray units use the transformer to provide current of the required voltage and amperage. These ma-

chines operate on the 110 or 220 volt, 10 ampere commercial currents and deliver to the x-ray tube ten milliamperes at forty or forty-five thousand volts.

The tungsten filament in the tube is heated by the current from a step-down transformer at 12 volts.

Since the transformer operates on alternating current only, if the available commercial current is direct, it can be made to operate a direct current motor which in turn runs an alternating current dynamo producing the alternating current which is required for the transformer. This motor and dynamo are usually built together in a compact unit both running on the same shaft, and is called a rotary converter.

Questions.

1. What English physicist is credited with the discovery of induced currents?
2. Name three electrical devices which depend upon induction for their operation.
3. Why are induced currents of short duration?
4. An induction coil operates on alternating or direct current?
5. How may the voltage of an induced current be increased?
6. Make a diagram illustrating the transformer.
7. What is the difference between a step-up and a step-down transformer?
8. Make a labeled diagram showing the essential parts of a dynamo.
9. Why are alternating currents used for long distance transmission?
10. What is meant by self induction?

Chapter VI

X-RAYS AND X-RAY TUBES

1. **The Disruptive Discharge.** If the terminals of an active electric machine are brought sufficiently near together, sparks will be observed to pass between them. This is called a disruptive discharge. The discharge is accompanied by heat, light, and sound. The path of the spark is zigzaged and forked.

The distance through which an electric spark will jump in air varies with the size and shape of the electrodes, the temperature, barometric pressure, and humidity of the air. The distance in air through which the spark will jump is used as a rough means of measuring the potential of a current. A sparking distance of one inch indicates a potential of about 28,000 volts; two inches, 42,000 volts; three inches, 56,000 volts; five inches 85,000 volts; etc.

2. **Effect of Pressure upon the Discharge.** If the electric discharge is caused to take place in a region of lowered atmospheric pressure, very marked changes take place in the character of the discharge.

A. The Geissler Effect. Geissler studied the effect of low pressure on the character of the electric discharge. In his investigations he employed a tube having plat-

inum wires sealed through the glass. By attaching an air pump to a side opening he was able gradually to exhaust air from the tube and to observe any changes taking place in the nature of the discharge between platinum wires. When the pressure is reduced to about one-thousandth of an atmosphere, the cathode is surrounded by a luminous layer which extends for a short distance into the tube. Next to this is a dark space. Beyond the dark space and extending to the

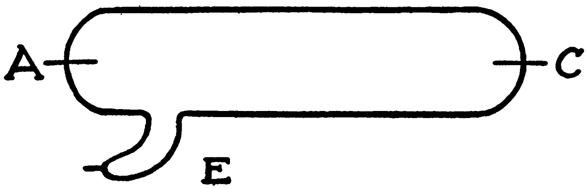

Fig. 32. Vacuum Tube for Showing the Effect of Pressure upon the Character of the Electric Discharge.

anode end of the tube is a peach bloom glow. Still further reduction of the air pressure results in an increase in the length of the dark space.

B. The Crookes Effect. When the exhaustion of the tube has proceeded until the dark space occupies the entire length of the tube, which takes place at about one-millionth of an atmosphere, the walls of the tube became brilliantly fluorescent. The luminous effect is limited almost entirely to the walls of the tube. A tube which has been exhausted to this stage is known as a Crookes tube.

C. Theory of Conduction through Gas. The phe-

nomena incident to the passage of an electric current through varying atmospheric pressures are of little practical value in x-ray work, but are closely associated with its history and development.

According to our electron theory any gas, as well as other forms of matter, consists of minute solar systems in which minute negative charges called electrons revolve in orbits about a positive nucleus. Undisturbed the gas is inactive electrically. However, any molecular disintegration is characterized by the liberation of free negative electrons which leave the molecules electrically positive. These disintegrated parts of molecules are called ions, and the process is called ionization.

Ordinary air contains a relatively small number of ions surrounded by inactive gas molecules. However, under the influence of an electric field the ions do move: the negative ones toward the positive side of the field and the positive ones toward the negative side. At low voltages this movement is very limited, and the amount of current that is transmitted through the gas is therefore very small. As the voltage is raised, a point is finally reached where the force acting on the ions is so great that they acquire sufficient speed to disintegrate other gas molecules with which they collide. This process continues, and there is a mass movement of ions toward the respective electrodes. A spark is established, and a large current passes.

In a partial vacuum, however, there are fewer mole-

cules, and there is greater freedom for the movement of the ions so that an active collision ionization occurs when comparatively low voltages are applied. Hence, increasing the exhaustion of a tube increases the ease with which a current can pass through it. Continued exhaustion, however, reduces the conductivity

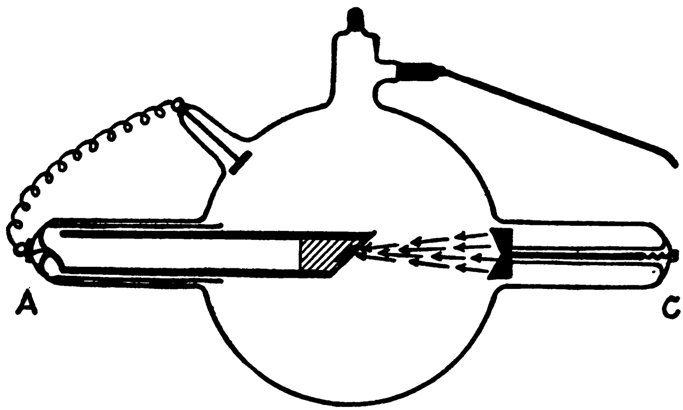

FIG. 33. Cathode Rays in Vacuum Tube.

because the supply of molecules for ionization is removed, and with a perfect vacuum a tube becomes a non-conductor.

The positive ions liberated by collision play a very important part in the conductivity of the tube for as they are driven against the cathode, they dislodge large quantities of electrons from the metal of the cathode, and these in turn are repelled by the cathode field to form the cathode stream or cathode rays.

D. Cathode Rays. We have seen that cathode rays

are fast moving electrons produced by a high voltage in a vacuum tube. These electrons are infinitely small particles of solid matter, and at times reach a velocity as high as 100,000 miles per second. These rays demonstrate their characteristics in various ways.

1. Mechanical Effect. Because of their great velocity the mechanical effects are very marked. When the electrons strike a target, their motion is arrested and transferred to the target.

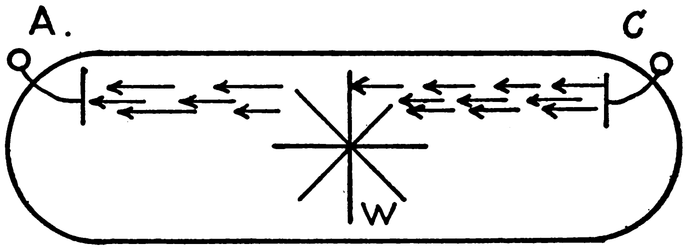

Fig. 34. Mechanical Effects of Cathode Rays.

The light paddle wheel shown in the diagram can be made to travel along the glass track inside the tube by projecting electrons from the cathode against the paddles.

2. Heating Effect. A piece of platinum mounted in the path of the cathode rays may be caused to glow or even to melt from the bombardment of the rays.

3. Deflection by a Magnet. Cathode rays proceed in straight lines except as they are deflected by a magnet.

4. May Be Focused. The electron stream may be

caused to impinge on a small area by means of a concave cathode.

5. Produce X-Rays. X-rays are generated when-

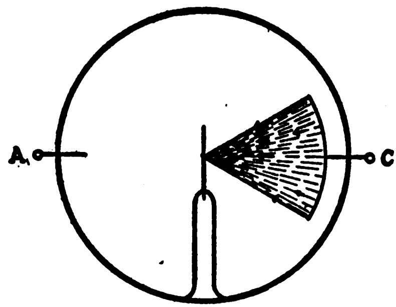

FIG. 35. Heating Effect of Cathode Rays.

ever a stream of electrons strike a solid object such as the anode of a vacuum tube. The wave length of these x-rays is determined by the speed at which these electrons strike the anode. The

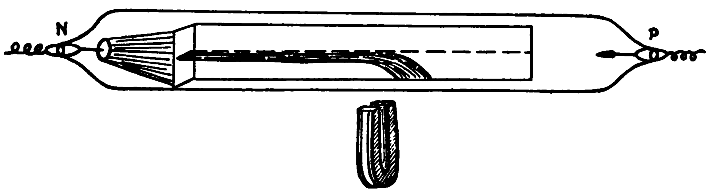

FIG. 36. Deflection of Cathode Rays by a Magnet.

greater the potential applied to the electrodes of the tube, the greater the speed of the electrons, and the shorter the x-rays produced.

3. Roentgen Rays. The discovery of X-rays came as the result of systematic investigation. Following

the discovery of methods to produce currents having high voltages a great deal of experimental work was

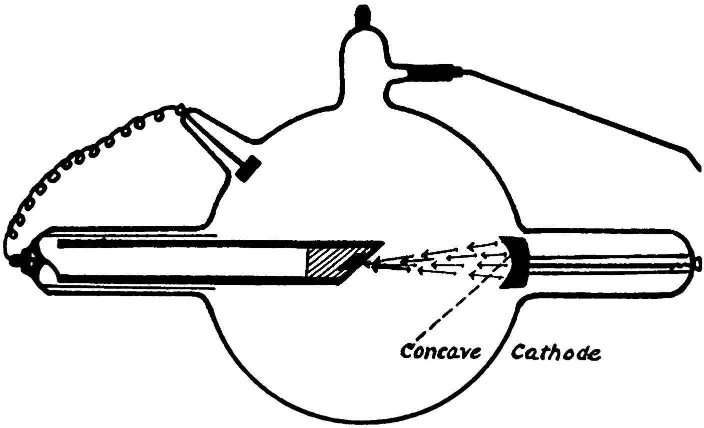

FIG. 37. Focused Cathode Stream.

undertaken to determine the characteristics of these currents. After the development of efficient air pumps investigation was directed to the performance of these currents in a vacuum. The names of Davy, Faraday, Geissler, and Crookes are linked with the early work along this line. Some of these undoubtedly produced x-rays though they failed to detect them. With so many physicists interested in studying the dis-

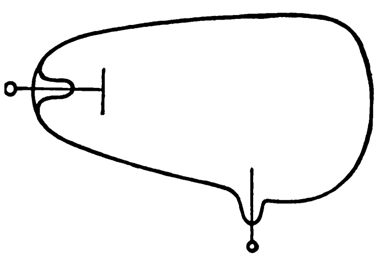

FIG. 38. X-Ray Tube of the Type Used by Roentgen.

charges of electricity in gases it was quite natural that Professor Wilhelm Konrad Roentgen, Professor of Physics in the University of Wurzburg, Bavaria, should be so engaged in 1895.

One day while working with a vacuum, or Crookes' tube, which he had completely covered with black paper Roentgen observed that some barium platino-cyanide, spread on a cardboard and lying on the table some distance from the tube, became brilliantly illuminated although the rest of the room was completely dark. He also noticed that various substances placed between the tube and the cardboard cast shadows on the cardboard. In this way he discovered that the cause for the fluorescence was coming through the black paper from the vacuum tube. Recognizing that he had discovered a new kind of radiation but unaware of the true nature of the rays he called them "x-rays." In honor of the discoverer they have since been called Roentgen rays.

A. Properties of X-Rays. X-rays are a form of radiant energy or wave energy possessing considerable similarity to visible light, though the wave length of visible light is about 10,000 times longer than that of x-rays. The shortness of the wave length enables these rays to pass between the atoms and the molecules of many solid substances. The outstanding properties of x-rays are that they:

1. Are not regularly reflected or refracted.
2. Are reflected and refracted by crystals.

3. Are not focused by a lens.
4. Cannot be deflected by a magnet.
5. Travel in straight lines.
6. Are invisible and travel as waves.

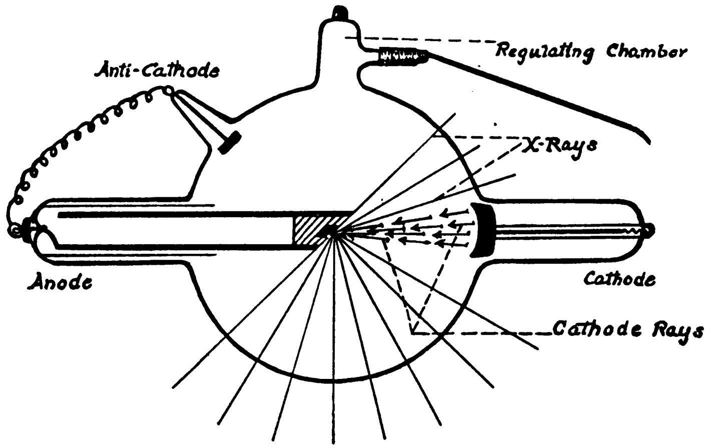

FIG. 39. Early X-Ray Tube.

7. Will affect a photographic plate.
8. Travel at the same speed as visible light.
9. Are capable of penetrating matter which is opaque to ordinary light.
10. Produce chemical and biological changes.

The most important characteristics of these rays from our standpoint are (1) their ability to pass through many substances which are opaque to ordinary light and (2) their effect upon the photographic emulsion.

B. Production of X-Rays. When the velocity of electrons is changed, a disturbance results which sets up

waves which we call electromagnetic waves. Some electromagnetic waves are long, and others are very short. The more rapid the disturbance of the electrons, the shorter the waves produced. Some of these waves are visible, and others invisible. In the case of the x-rays the high speed electrons are stopped in their flight through the tube by a target of metal at the anode. X-rays result from this loss of velocity. There are four distinct steps in the production of x-rays.

1. The breaking up of molecules and the production of electrons.
2. Imparting high speed to the electrons.
3. Focusing the stream of electrons (cathode rays) upon a small target.
4. Suddenly stopping these high speed electrons.

As we have previously noted, the electrons are produced by the disruption of molecules in collision with other electrons and with the x-rays themselves. A voltage applied to the electrodes of the tube

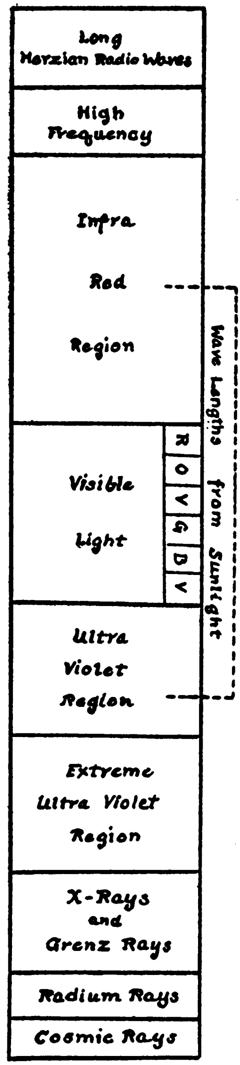

FIG. 40. Electromagnetic Spectrum

provides the speed. The concentration of the electrons on the target is secured by proper placing and shaping of the electrodes. The target itself must have a very high melting point to withstand the heat produced by the bombardment of the electrons when the tube is in operation. Tungsten is usually used for this purpose.

4. **X-ray Tubes.** Professor Roentgen discovered the x-rays while he was working with a Crookes' vacuum tube. This type of tube was modified somewhat for x-ray work and was called the "gas" tube because a small quantity of air or "gas" was left in the tube to start the ionization which results in the conduction of electricity.

A. Gas Tubes. Three electrodes were sealed into the tube, called anode, cathode, and anticathode. The anode and anticathode are connected so their potential is the same and positive. The cathode is the negative electrode from which the cathode rays are liberated. The cathode is so shaped as to focus these rays upon a target in the anode.

Gas tubes are spoken of as being hard or soft. A hard tube is one with a high vacuum which requires a high potential to conduct electricity and produces x-rays having great penetration. A soft tube gives off rays having low penetrating power. As a tube is operated, it becomes heated, and the result is a rarefaction of the remaining gas. From the Theory of Conduction of Electricity through Gases we learned that

the volume of electrons varied with the degree of vacuum, and if the air or gas were removed beyond a certain point, the tube becomes a non-conductor. Constant adjustment of the potential to compensate for these changes in vacuum required a great deal of manipulation which resulted in loss of time and frequent failures. Various devices were incorporated in the tube in an effort to eliminate this difficulty. A side tube, known as a regulating chamber, was built into the tube. This regulating chamber contained ingredients which would give off gas when the tube became heated thus offsetting the increase in the vacuum due to operating the tube.

B. Hot Cathode X-ray Tubes. While Edison was seeking for a suitable material from which to make filaments for his electric light bulbs, he made the observation that heated metals emitted electrons. This is known as the thermionic emission of electrons, and was made use of by Dr. W. D. Coolidge employed by the General Electric Co. at Schenectady, New York, in the production of a new type of x-ray tube. In the "gas" tube electrons for the cathode stream came from the ionized gas and from the bombardment of the cathode by positive ions. The operator was unable to control either source. In the Coolidge tube the air is exhausted beyond the point where there are any ions remaining to act as triggers and the supply of electrons is completely controlled by regulating the amount of current which is allowed to pass through

the cathode filament. Coolidge tubes have resembled the gas tubes in appearance, being flasks instead of tubes. Recently, however, the manufacturers are making them tube shaped and some are enclosed in a metal covering except at the point where it is desired to have the rays leave the tube.

1. Standard Coolidge Tube. In the tube designed by Coolidge the cathode is a spiral filament of

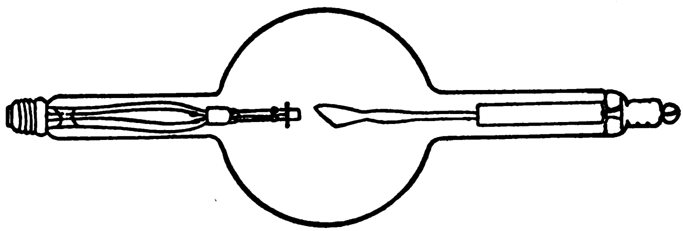

FIG. 41. Standard Coolidge Tube.

tungsten wire heated to a high temperature by an electric current. The target is usually a solid piece of tungsten embedded in a solid copper anode. Copper is used because of its ability to conduct the heat away from the target. The Coolidge tube has but two electrodes, the cathode and the anode.

2. Radiator Coolidge Tube. Rectified Current. The step-up transformer supplying a high potential to the tube delivers alternating current. If the electrodes of the x-ray tube were connected to a source of alternating current, the anode and cathode would be alternately positive and negative. To produce usable x-rays it is necessary that there

be a steady stream of electrons moving from the filament to the target. This is accomplished by inserting a mechanical means of making the current unidirectional or by the use of the more modern valve tubes, or by using self-rectifying x-ray tubes.

The ordinary Coolidge tube will operate satisfactorily on alternating current without the inter-

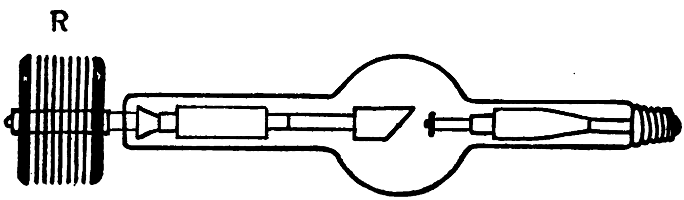

FIG. 42. Radiator Coolidge Tube.

position of rectifying devices providing there is some means of keeping the target cool so that it will not give off any appreciable number of electrons to oppose those coming from the cathode. Hence, in their self-rectifying or radiator tube the General Electric Co. attached a series of discs at the end of the anode which extends out of the tube. These discs act as a radiator to cool the anode.

3. Oil Immersed Coolidge Tube. In some types of x-ray apparatus the tube is immersed in oil with the transformer. The oil serves the double purpose of cooling the anode and insulating the transformer. A tube of this type which is being used

in certain dental x-ray units is only 4½ inches in length.

Some means of cooling the anode is often pro-

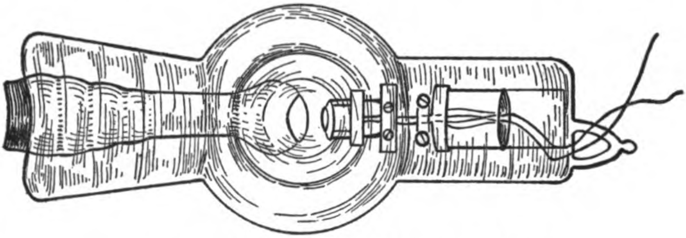

FIG. 43. Oil Immersed Coolidge Tube.

vided on very high power tubes for another reason. The cooling device may be needed to protect the anode from over heating or possible melting and may have no part in rectifying the current, this function being taken care of by other devices designed for that purpose.

4. Water Cooled Coolidge Tube. The water cooled

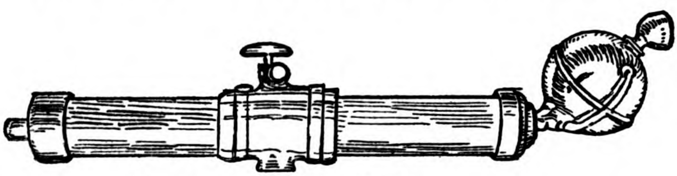

FIG. 44. Water Cooled Coolidge Tube.

tube is constructed for heavy work. Water is circulated through the anode thereby keeping the target cool.

5. Mechanical Rectification. For certain types of

x-ray work self-rectification is inadequate, and it is necessary to use a special means of providing a unidirectional current to the tube. One way of accomplishing this is by means of a revolving disc attached to a synchronous motor. This diverts the phases of the current from the step-up transformer so that the flow is all in one direction through the tube.

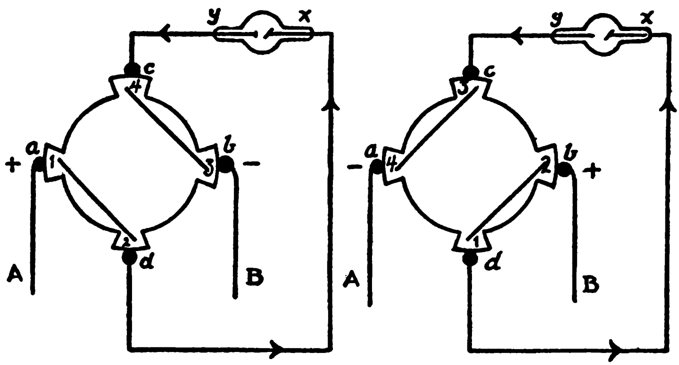

Fig. 45. Mechanical Ratification.

6. Valve Tube Rectification. The valve tubes or kenetrons, as they are called, operate on the same principle as the Coolidge x-ray tubes, thermionic emission. By the use of a hot filament to give off a stream of electrons one phase of the current is permitted to pass through the tube, and the opposite phase is suppressed. By using four valve tubes properly connected no phase is suppressed. The chief advantage of valve tube rectification over mechanical rectification is the lack of noise.

7. Tube Focus. Tubes are referred to as having broad, medium, and fine foci. By shaping the cathode the electrons can be focussed to strike a small area on the target. If this area is less than

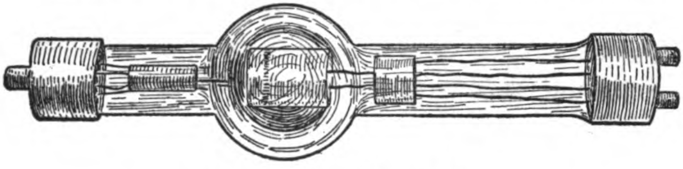

FIG. 46. Kenetron Tube.

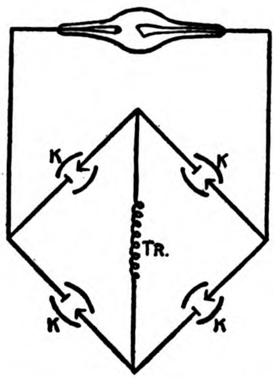

FIG. 47. Valve Tube Rectification (4 tubes).

4 mm. in diameter, the tube is called a fine focus tube, 4 to 7 mm. medium focus, and over 7 mm. broad. A broad focus tube can run longer without overheating than a fine focus tube.

If a large volume of x-rays is needed, a broad focus tube is indicated, but a fine focus tube gives sharper detail.

5. **X-ray Apparatus.** We have now traced the principal scientific advances which lead to the construction of x-ray machines. Electricity was needed, electricity of a particular type having a very high voltage, fifteen thousand to several hundred thousand volts. The amperage of this current must be very low, being measured in milliamperes, 5 to about 60 ma. Even after

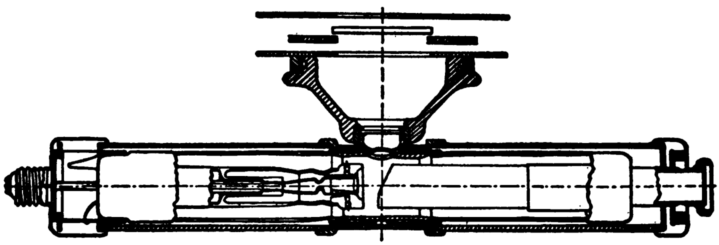

FIG. 48. Line Focus Tube.

we had commercial electricity, it remained for Faraday to show the way to alter this current to produce this potential necessary for the production of x-rays.

A vacuum tube is the other prime essential of any x-ray apparatus. Experiments in the behavior of electricity in gases and the application of the principle of thermionic emission of electrons have led to our present perfection in tubes.

The apparatus itself has gone through a considerable transition from the cumbersome, noisy, static machines which produced their own high tension current, to the compact, quiet, unimposing apparatus of today which operates on the transformer.

Some of the rapid advance in this field can be attributed to the demand for simplified and portable equipment during the war.

Due to the relative uniformity of the tissues of the mouth and the teeth it has been possible to standardize dental x-ray apparatus to a marked degree. We have dental units which occupy very little space, are almost foolproof, and give splendid results.

Not only have the manufacturers produced apparatus to meet all possible requirements, but much has been done to safeguard the operator and patient. The ultimate in safety is realized in the oil immersed apparatus which combines transformer and tube in a single container and eliminates the high tension lines.

Questions.

1. Is there any relation between spark gap and voltage?
2. Describe the Geissler Effect.
3. What is meant by ionization of gas molecules?
4. Cathode rays travel in which direction?
5. Distinguish between cathode and x-rays.
6. How are x-rays produced?
7. How do Coolidge tubes differ from gas tubes?
8. Are all tubes that have a hot cathode filament Coolidge tubes?
9. Why should the anode be kept cooler than the cathode?
10. Are thermionic emission tubes the same as Coolidge tubes?

CHAPTER VII

PROCESSING (PHOTOGRAPHIC CHEMISTRY)

1. In order that we may be able to view the results after the x-rays have penetrated the various tissues of the body and cast their shadows upon the film, we must subject the film to the same procedures that are necessary in photography. The fact that many x-ray negatives are ruined or rendered unsatisfactory because of lack of attention to details in carrying out these procedures makes it imperative that we give considerable attention to this phase of the work.

2. **The Photographic Emulsion.** Several of the salts of silver are sensitive to light. Of these salts, silver bromide is the most satisfactory. In their effect upon the silver bromide, x-rays act similarly to light rays, though the x-rays have a wave length many times shorter. The effect of the rays upon the film is not a visible one, but a change is brought about, nevertheless, which renders the silver bromide more sensitive to the action of certain chemicals.

A. Manufacture of Film. Silver nitrate is dissolved in gelatin and mixed with silver bromide and a small amount of potassium iodide in water. The chemical

reaction which ensues results in the formation of two insoluble silver salts, silver bromide and silver iodide, which remain suspended in the gelatin in the form of minute grains. At this stage these salts react very slowly to the rays, and very long exposure would be required. By heating this emulsion of silver salts and gelatin the silver grains expand. The larger the grains, the more rapid will be their reaction to the rays. When an emulsion having the desired speed is reached, it is allowed to cool and solidify. It is next shredded and washed to remove soluble impurities. The emulsion is then carefully melted and poured over sheets or films of celluloid or on glass plates. These are carefully dried and are then ready for use. For years only glass was used, and the term photographic plate is frequently heard to this day though glass is now seldom used. Some films have this emulsion on both sides and are known as duplitized films while others have but one surface coated and are known as single coated films. This entire process must be carried out in a "dark room" with a red light since the red rays have but little effect on the silver compounds.

3. **Effect of the Rays on the Emulsion** (The Latent Image). When these silver salts on the film or plate are exposed to light rays or to x-rays, they are decomposed and though there is no visible change, they are rendered sensitive to reducing agents. We do not know just what takes place in the silver salts when

they are exposed, but we speak of this effect as the latent image. The effect of the rays depends upon the strength of the rays and the length of the exposure.

4. **Effect of Reducing Agents on Exposed Film.** Although there is no visible change in the film after it has been momentarily exposed to x-rays, the latent image becomes visible when the film is placed in a reducing solution. There are a number of chemicals which may be employed as developers, but they are all reducing agents, that is they are capable of being oxidized. Reduction and oxidation always take place together and in the same amounts.

The reducing agent is able to act rapidly upon the silver salts which have been affected by the rays and only very slowly upon those which have not been so affected. The reducer reduces the silver bromide leaving the silver on the film as metallic silver. This action takes place more rapidly where the rays have acted more intensely, that is where the decomposition of the silver salts has advanced furthest, and less rapidly on those parts of the film where the action of the light rays or x-rays has been less intense. The image which the developing solution brings out appears black because the grains of silver are small and irregular in shape. We think of silver as being white, but if we break it up into minute particles, it appears grey, and the tiny sponge-like grains of silver in the emulsion are quite black.

5. **Composition of the Developing Solution.** So far we have referred to the developing solution merely as a reducing agent which removes the bromide from the silver bromide. Though the reducer is the chief constituent in any formula for a developer, there are other ingredients which go to make up the solution, and each of these ingredients has a definite part to play in producing the desired results. Not only must there be additional ingredients, but these different ingredients must be properly balanced in their relation to each other and to the emulsion. Solutions containing only reducing agents are as a matter of fact practically useless. They do not keep well, and they are extremely slow in their action. In order that we may know what to expect from a developing solution and further to enable us to account for and correct difficulties when they arise, we shall consider the action of each ingredient.

Though there are various formulae for developing solutions, there are five essential ingredients in all of them.

1. A Reducer—Hydroquinone and Elon
2. A Preservative—Sodium Sulphite (Na_2SO_3)
3. An Accelerator—Sodium Carbonate (Na_2CO_3)
4. A Fog Restrainer—Potassium Bromide (K Br)
5. A Solvent—Water (H_2O)

A. Hydroquinone and Elon. The reducing agents are effective only as long as they are capable of being oxidized. Exposure to the air and heating, as well as

developing of the films, results in an oxidation and hence a deterioration of the reducing agents. An old or worn out solution may be recognized by the fact that it turns dark. The temperature of the solution is important for another reason also. Hydroquinone is extremely sensitive to thermal changes. Only a range of three degrees is permissible, from 65°F. to 68°F. Above 68°F. the action proceeds too rapidly while below 65°F. hydroquinone becomes inactive.

The Hydroquinone brings out contrast and the Elon gives detail.

B. The preservative (Sodium Sulphite) acts to keep the oxidation at a minimum. The reducing agents have a great affinity for oxygen, and because of the oxygen in the air they spoil readily on exposure. By adding the sulphite of soda, which has a greater affinity for oxygen, the developer is protected and its period of usefulness prolonged.

C. The Accelerator (Sodium Carbonate). The reducing agents are effective only when in an alkaline solution. Sodium carbonate hastens the process of development by softening and opening the pores of the emulsion so that the developer can come in contact with the silver below the surface.

D. The Fog Restrainer (Potassium Bromide). This prevents the silver bromide which has not been acted upon by the rays from being reduced.

E. The Solvent or Vehicle. Water, preferably distilled water, should be used in making up the devel-

oping solution. Water which has not been distilled is apt to contain chemicals or mineral matter which has an injurious effect upon the solution or upon the silver salts of the emulsion.

6. **The Chemistry of Fixation.** In the process of development only those areas of emulsion were affected which had been exposed to the rays. Those areas which had been greatly affected by the rays were reduced more completely than those areas which were only slightly exposed. In other words, the reduction was in proportion to the exposure. It now remains to remove that portion of the silver salts which has not been reduced or developed. This is accomplished by means of a "fixing solution." This fixing solution also contains several ingredients.

A. Hyposulphite of Soda (Sodium Thiosulphate) $Na_2S_2O_3$. This ingredient is commonly called hypo, and its function is to dissolve the undeveloped silver salts.

B. Acetic or other acid. Though the film is washed by dipping it into water after taking it out of the developer and before placing it in the fixing solution, a certain amount of the alkaline developer is carried over into the fixing bath. The function of the acid is to neutralize any alkali which may have been retained on the film when it is taken out of the developer. If the fixing bath becomes alkaline, the sodium thiosulphate acts itself as a developer and spoils the film.

C. Alum. Potassium alum or chrome alum are com-

monly used as hardeners, that is they have the property of shrinking and tanning the gelatine which has become softened and swollen in the developer. Its use is particularly important in hot weather.

D. Sodium Sulphite. As in the developing solution sodium sulphite is used to preserve the solution from oxidation. Oxidation of the fixing solution turns it brown and milky and results in a staining of the films.

E. Water. As in the case of the developer water is the solvent used in making up a fixing solution. As the developer becomes exhausted and less effective, it turns dark in color, but when the "hypo" or "fixer" becomes white or cloudy, it should no longer be used.

7. Dark Room Requirements.

A. The place where the developing and finishing is to be carried on may vary in size from a small light proof box about two feet square to a large fully equipped room. The available space and the volume of work will determine which type is indicated. Regardless of the size, however, there are certain requirements of any dark room.

The first essential of a dark room is that it be possible to exclude all light from without. Light leaking in around a door has fogged many films. It has been common practice to paint dark rooms black. This is not essential and contributes nothing to making the room dark. There is no reason why the walls should not be as attractive as in any other room.

B. The illumination within the dark room must be

photographically safe. There are various safe lights on the market. The Wratten 6A safelight provides ample illumination and is safe when used with a bulb of the proper wattage. Ruby glass electric bulbs may be used, but red paint over a clear glass does not afford protection. Any illumination should be checked. To do this, exclude all light from the room. Remove a film from its package and attach a paper clip across its surface, and place the film where the films are usually handled. Allow the film to be exposed to the developing light for five minutes. Now remove the clip and develop the film in total darkness. If the outline of the paper clip can be detected the light is not safe. The light from a cigaret will fog a film. It must be remembered that no light is absolutely safe and development should always be carried on as far from the source of light as possible, and the films should be handled speedily so as not to

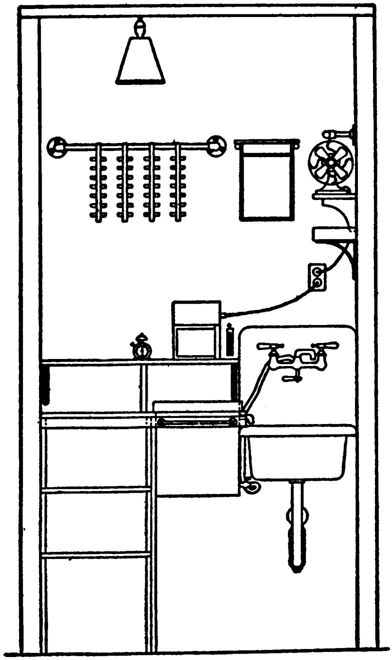

FIG. 49. Model Dark Room (Eastman)

expose them to even the "safe light" for a longer time than necessary.

C. Ventilation is often overlooked in planning a dark room. This is especially important where a large amount of work is done and someone must stay in the dark room for considerable time. It is possible to in-

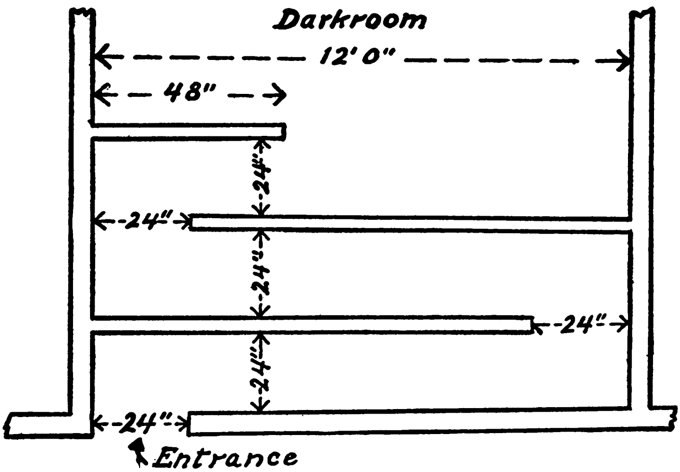

FIG. 50. Maze Entrance to Dark Room.

sert air vents in a door or wall which will permit a change of air and do not allow light to enter. If sufficient room is available, a maze may be substituted for a door. This not only allows for a better circulation of air but makes it possible for one to enter or leave the dark room at any time without danger of fogging films which may be exposed. If the room has a window, this may be opened when films are not exposed, and a light proof door can be provided to shut

out the light during the time that films are being processed. An electric fan is frequently necessary to change the air. If the volume of work does not warrant equipping a room for this work, very satisfactory results may be obtained by use of a developing cabinet.

D. Tanks. The type of tanks or basins which one will find best for holding the processing solutions will depend very largely upon the volume of work. Where an exposure is made only occasionally, as is usually the case in an office where the dentist is conducting a general practice, small glass specimen jars or even tumblers serve the purpose very well. The small individual hangers are suitable for this technic. The solution should be kept in stoppered bottles to prevent deterioration when not in use.

FIG. 51. Developing Cabinet.

When a large number of films are turned out daily, it is advisable to have tanks that will hold several gallons of solution and to have them so arranged in relation to running water that a constant temperature can be maintained. The dimensions of the tanks should be such as to accommodate the hangers to which the films are attached while being developed and finished.

E. Processing Solutions. The chemicals for developing and fixing may be purchased in bulk from x-ray

or photographic supply houses. With the aid of a small scale the ingredients can be weighed out and dissolved according to formulae such as the following:

1. Formula for Developing Solution

	Avoirdupois	*Metric*
Elon—reducing agent giving detail	1/4 oz.	2.0 gm.
Hydroquinone—reducing agent giving contrast	1 oz.	7.7 gm.
Sodium Sulphite—preservative	9 1/2 oz.	74.2 gm.
Potassium Carbonate—alkaline accelerator	4 3/4 oz.	37.1 gm.
Potassium bromide—fog restrainer	233 gr.	14.2 gm.
Water—(distilled)—vehicle ..	1 gal.	1000 c.c.

2. Formula for Fixing Bath

Hypo—solvent for silver bromide	32 oz.	250 gm.
Water—warm—vehicle	96 oz.	750 c.c.

When dissolved, add

Sodium sulphite—preservative	4 oz.	40 gm.
Acetic acid (glacial)—acidifier	4 3/4 oz.	50 c.c.
Alum—hardener	4 oz.	30 gm.
Water—vehicle	32 oz.	250 c.c.

The developer and fixer may also be purchased in prepared packages ready to mix in water. These packages come in a variety of sizes to make either 12 oz., one gallon, or five gallons of solution.

In certain large cities it is also possible to have the solutions delivered to you, all prepared, in gallon bottles. A trial will determine which is the better method for you under the conditions with which you are working. The prepared package provides an easy quick

way of making up a standard solution, but if one wishes to alter the formula for any reason, he may do so more readily if he purchases the chemicals in bulk.

F. Films. The manufacturers of x-ray film have provided a variety of films for dental use. The Eastman Company list theirs as follows:

1. For Intra Oral Exposure
    a. Periapical Dental X-ray Films.
        (1) Regular—1¼" x 1⅝"—slow
            Single coated, one or two films per packet
        (2) Extra Fast—1¼" x 1⅝"—fast
            Single coated, two films per packet
        (3) Radiatized—1¼" x 1⅝"—medium
            Double coated, one or two films per packet
        (4) Radiatized #0—⅞" x 1⅜"—medium
            Double coated, two films per packet
        (5) Occlusal—slow
        (6) Occlusal—fast
    b. Bite-Wing Dental X-ray Films (Interproximal)
        (1) #0—slow—single coated, one film per packet
        (2) #1—slow—single coated, one film per packet
        (3) #2—slow—single coated, one film per packet
        (4) #3—slow—single coated, one film per packet

2. For Extra Oral Exposure
   (1) 5″ x 7″—ultra speed, double coated
   (2) 6½″ x 8½″—ultra speed, double coated
   (3) 8″ x 10″—ultra speed, double coated

Films may be kept in the dark room if space permits and providing they are protected from stray x-ray radiation, from moisture, from heat, and from chemical fumes. A metal cabinet or lead-lined box usually answers the purpose.

G. Miscellaneous Equipment. As the proper timing of the chemical reactions which take place between

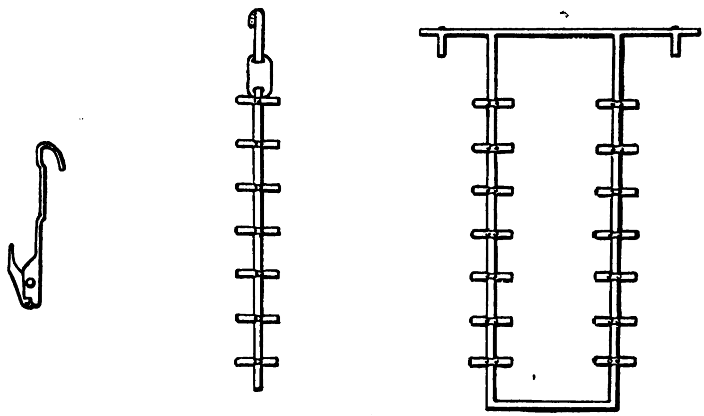

FIG. 52. Film Hangers.

the solutions and the x-ray films is very important, an interval timer should be a part of the dark room equipment. An interval timer is an alarm clock which may be set to ring after a desired number of minutes have elapsed.

Since the chemical reactions are also dependent

upon the temperature of the solutions, a thermometer is an indispensable part of the dark room equipment. Film hangers are available in a variety of shapes and sizes from the individual clips which are used to hold the films when the small tanks are used, to those which hold fourteen films, the number commonly used in covering all of the teeth in a mouth. Special hangers are also made for the larger extra oral films.

Following the washing of the films it is necessary to have some convenient place to dry them, where they may come in contact with dry, clean air. Special dryers with fan and heating units are helpful where a large number of films are being used.

H. Dark Room Technic. There are three methods of developing an x-ray film: the factoral, the visual, and the time-temperature method.

1. The Factoral Method. By the factoral method the developing time is determined by multiplying the time required for the first appearance of the image, after the film has been placed in the developing solution, by the numerical factor of the particular developing agent used. This method was formerly used a great deal in the field of photography, and has some advantages in certain types of experimental work with x-rays.
2. The Visual Method. The process of reduction may be followed by the changing color of the film while in the developing solution. One experienced in the work is able to tell quite accurately when

the reduction has proceeded to the desired point. Following the exposure the film is taken into the dark room and removed from its light proof packet. The film is placed in a tray or tank of developer from which it is removed at frequent intervals to observe, under the safe light, the extent of the chemical action. When it is thought to be properly developed, the film is removed from the developer, rinsed, and placed in the fixing solution. This method may produce very good results in some hands, but the element of chance enters into it so largely that it is not a safe procedure for general use. It is often used in outdoor amateur photography where it is impossible to control and difficult to estimate the amount of light which is to come in contact with the film. In x-ray work today it is possible to accurately regulate both the volume of the x-rays and the time which they act upon the film.

3. The Time-Temperature Method. Developing is a delicate chemical process and yet the procedure can be standardized so that it is a relatively simple matter, and the results are uniformly satisfactory. This method is based upon the action of a developer of a given strength acting for a given length of time at a given temperature.

Also this method serves as a definite check upon the exposure time. If correctly exposed, a film will be properly developed in five minutes in a fresh

solution at 65°F. On the other hand, if the negative lacks density after being developed by this method, it is apparent that a longer exposure is indicated. If it is too dense, the exposure has been too long. With the variable factors of the visual method it is very difficult to tell whether the exposure was faulty and, if so, in which way.

I. Cleanliness. Due to the sensitiveness of the emulsion and the ease with which the solutions can become contaminated, cleanliness in the dark room procedure is essential. Utensils which are used for holding the solutions, or in their preparation, must be washed clean. Chemicals must not be allowed to dry on floor or walls and later get into the air. The films should be handled as little as possible and only on the edges with clean, dry hands.

Questions.

1. What is a photographic emulsion?
2. What is the Latent Image?
3. Is the developer a reducing or oxidizing solution?
4. Of what is the developing solution made, and how does each ingredient function?
5. Does the fixing solution act on a film that has not been exposed?
6. List the ingredients which go to make up a fixing solution, and describe the function of each.
7. What color should dark rooms be painted?
8. How would you test the safety of a dark room light?
9. Describe the time temperature method of development.
10. How can your method of developing assist you in determining the proper exposure time?

Chapter VIII

NORMAL ANATOMICAL LANDMARKS

1. There are two characteristics of x-rays which make them of value in diagnostic work: X-rays penetrate material which ordinary light is unable to penetrate, and second, they have the same effect on the photographic emulsion as ordinary light. We have observed how the rays affect the emulsion and how we must treat the film in order to make this effect visible and capable of interpretation. Now let us consider the penetrating qualities of x-rays and see how they have diagnostic value.

2. **X-rays Produce Shadow Pictures.** If these x-rays merely passed through tissue like light through a piece of clear glass, they would have no diagnostic value. They would reveal nothing of the composition or structure of the tissue through which they passed. However x-rays vary greatly in penetrating power. The rays are not all the same length and the short waves have much greater penetration than the long ones. We can produce x-rays which will readily pass through considerable thickness of steel and we can produce other x-rays that are so lacking in penetration

that they are scarcely able to pass through the glass of the x-ray tube. If we were to use the highly penetrating short rays, they would pass through the tissues of the body so readily that no shadows would be cast on the emulsion. As far as we could detect all parts of the film would have been subjected to an equal amount of radiation. On the other hand, were we to use the "soft" or long rays which we find near the ultraviolet part of the spectrum, we would again fail to produce a shadow on the emulsion for the rays would be completely absorbed by the tissue before reaching the film. For example, the x-rays which are used in engineering projects to detect flaws in iron and steel would pass through the tissues of the body with so little loss due to absorption of the rays by the tissues that the film would be practically uniformly exposed. If we used the long (Grenz) rays which are used in x-raying insects, flowers, microscopic sections of tissue, etc., the rays would be so completely absorbed that they would not reach the film. It is thus evident that the rays must be suited to the material with which we are working. We must have rays capable of penetrating the denser structures and yet not so powerful as to "burn out" the less dense, finer detail. In other words, the rays must be capable of casting shadows which vary in intensity inversely as the tissues vary in density. From all this we see that the x-ray picture or negative is a shadow picture and as such can only give us information as to the relative den-

sities of the tissues through which the rays have passed.

3. **Necessity for Knowledge of Anatomy.** After we have the apparatus to produce suitable rays, a knowledge of the anatomy of the tissues with which we are to work is essential, in order to produce x-ray negatives which are adequate for intelligent interpretation. Tissue through which the rays are unable to pass are spoken of as radiopaque, and tissues through which the rays pass are known as radiolucent. There are varying degrees of radiolucency and radiopacity. A tissue may be radiopaque in comparison with one tissue and radiolucent as compared with another. Also tissue which is radiopaque to certain x-rays may be radiolucent to rays having a greater penetration. It is necessary to know the relative radiopacity or radiolucency of the tissues with which we are dealing. It is also necessary to know and be able to recognize the various anatomical landmarks so that we can correctly orient the shadows when they have been made visible on the x-ray film.

4. **Limitations.** X-ray negatives have become an almost indispensable adjunct to making a diagnosis of mouth conditions. They are not by any means adequate in themselves, and if not properly taken and finished, they cease even to be adjuncts. There has been a tendency to lean too heavily on the x-ray, forgetting the value of careful inspection, palpation, percussion, response to thermal changes, and interpretation of the

various symptoms of pain. The x-ray is to be used only in conjunction with all the other diagnostic means at our disposal.

A. We must not expect the x-ray negative to:

1. Serve as a microscope.
2. Give stereoscopic vision.
3. Conclusively determine the vitality of the pulp in all cases.
4. Show whether decay or fillings encroach on the pulp.
5. Accurately serve to diagnose maxillary sinus conditions.
6. Determine the virulence of the infection.
7. Tell whether the infection has been of long or short duration.

B. Good quality dental roentgenograms should:

1. Show varying degrees of density in the tissues (normal or abnormal) which have been exposed to the rays.
2. Determine the vitality of the pulp when pulp canals are filled with some substance opaque to the x-ray.
3. Disclose obscure cavities.
4. Assist in determining the number and shape of roots.
5. Indicate the presence or absence of impacted teeth.
6. Indicate the presence or absence of teeth which have failed to erupt when due.

7. Disclose the presence of supernumerary teeth.
8. Reveal the existence and extent of fractures of the jaw.
9. Reveal foreign bodies lodged in the jaw or adjacent soft tissue.
10. Disclose faulty dental work.
11. Detect the existence of chronic bone conditions.
12. Reveal granulomas, cysts, and pulp stones.
13. Demonstrate the extent of bone destruction resulting from infection.
14. Cast shadows of the various sinuses, foramen, canals, and processes which are within the field of the rays.

In producing x-ray negatives of the teeth and jaw we encounter varying degrees of density, and since the density of the tissue controls the amount of radiation which reaches the emulsion on the film, it is important that we be familiar with the relative density of these tissues. We may list them according to their relative density as follows:

Metallic restorations—crowns, fillings, etc.
Enamel
Dentine
Cementum
Lamina dura
Cancellated bone
Medullary spaces, canals, foramina, peridental membrane, soft tissue.

Tissues seen in the x-ray negative are:

A. Teeth

1. Metallic restorations—crowns, fillings, etc.
2. Enamel
3. Dentine
4. Cementum
5. Pulp

B. Alveolar process

1. Cancellated bone
2. Lamina dura

C. Peridental membranes

5. **Anatomical Landmarks.**

A. Landmarks of the Maxilla.

1. Nasal fossa
2. Incisive foramen (anteriar palatine foramen)
3. Median palatine suture
4. Tuberosity of the maxilla
5. The hamular process of the sphenoid bone
6. The coronoid process of the mandible
7. Malar bone—Zygomatic process
8. Tempero-malar-suture
9. Maxillary sinus
10. Posterior palatine foramen

B. Landmarks of the Mandible.

1. Mental process
2. Interdental canals

3. Genial tubercles
4. Mental foramen
5. Mandibular canal
6. External oblique ridge
7. Mylohyoid ridge

6. **Pathology.** It is not within the present scope to take up the detection of disease as revealed by the x-ray. It will suffice to state that the successful diagnosing of pathology depends very largely upon the accuracy of the student's knowledge of normal anatomy and normal physiology. It should be kept in mind, however, that the x-ray does not show disease, as such, but only the comparative density of the tissues which have been exposed to the rays. We may find radiolucent areas which from our knowledge and experience we associate with necrosis. However disease may affect the radiability of tissue in various ways. Fractures leave radiolucent areas between fragments. An accumulation of pus in the cancellous part of the jaw without involvement of the bone will obstruct the passage of the rays or if the pus is present between bone and periosteum, it may not alter the density enough to leave a record on the film. On the other hand destruction of the bone due to inflammatory processes will greatly facilitate the passage of the x-rays and a dark area will be recorded on the film. A darker or lighter negative may be due however to the age of the patient rather than to pathology.

Questions.

1. Do all x-rays have equal penetrating power?
2. Distinguish between short rays and long rays.
3. What is meant by the terms radiopaque and radiolucent?
4. Do x-rays reveal the presence of pus as such?
5. Do the x-rays reveal anything more than relative densities of the material through which they pass?
6. Name five anatomical landmarks which may be found in x-ray negatives of the upper teeth.
7. Name five anatomical landmarks which may be found in x-ray negatives of the lower teeth.
8. Do metallic restorations absorb the x-rays more or less than enamel?
9. What is the relation between light and dark areas on the negative and the density of the tissue?
10. Is the x-ray able to function as a microscope? Explain.

CHAPTER IX

EXPOSURE TECHNIQUE

X-RAYS produce shadow pictures, and we wish to have these shadows depict as nearly as possible the actual condition of the tissue not only in density, but in size and proportion as well. To illustrate the point, let us consider the shadow of a girl as cast upon the

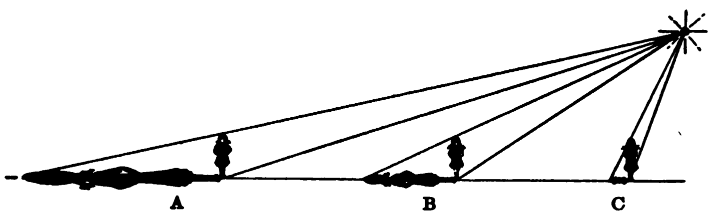

FIG. 53. *A*. Elongated Shadow. *B*. Optimum Position. *C*. Foreshortened Shadow.

sidewalk. When the sun is low in the early morning or late afternoon, the shadow is greatly elongated. Also the parts are out of proportion. The head and parts farthest from the sidewalk are elongated to a greater extent than the feet and other parts of the body closer to the ground. At noon when the sun is nearly overhead we have a shadow which is also distorted but

now is much shorter than the girl. However, there is a time of day when the shadow will be the same length as the girl and the shadow will then have the minimum distortion.

The ideal situation exists, however, when we have the screen and the person parallel and in close contact, with the light coming from a distance and perpendicular to both.

In general x-ray work it is usually possible to have

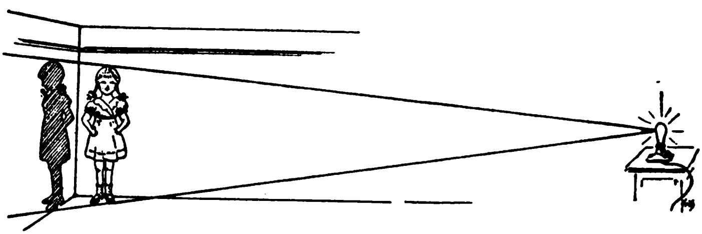

Fig. 54. Ideal Relation of Object, Screen, and Source of Radiation.

the screen (in this case the film) and the part to be exposed parallel, and to direct the x-rays perpendicularly to both. In intra-oral exposures, however, it is impossible to have the film and teeth parallel except in case of the lower molars. In taking x-rays of any of the other teeth we have a condition similar to the shadow of the girl upon the sidewalk. Though we are unable to place the film parallel to the teeth, we are able to direct the rays so that the shadow of the teeth will have practically the same dimensions as the teeth themselves and there will be relatively little distortion.

1. Angulation.

A. Vertical Angle. Whenever it is necessary to direct the x-rays upon structures which lie at an angle with the film, correct shadows will be obtained by adhering to the following rule: bisect the angle made by

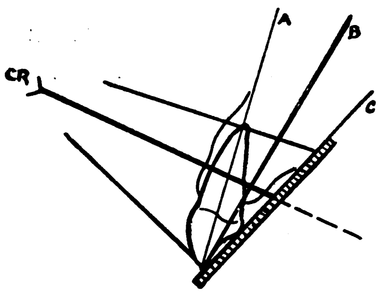

FIG. 55. Correct Vertical Angulation.

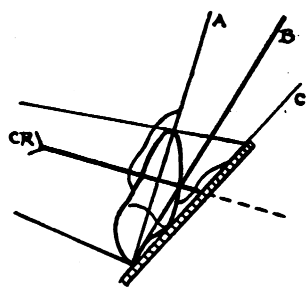

FIG. 56. Elongated Image.

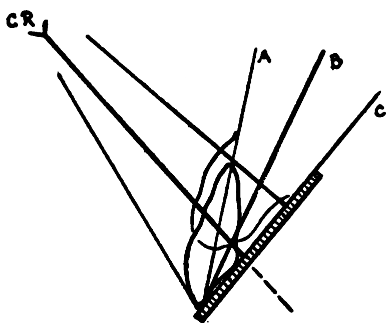

FIG. 57. Foreshortened Image.

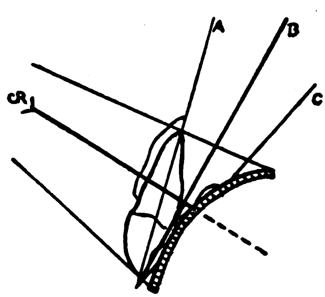

FIG. 58. Distortion Due to Curved Film.

the plane of the film with the plane of the object, and direct the rays so they will fall perpendicular to this bisecting plane.

B. Horizontal Angle. It is not sufficient that the shadows be the same length as the teeth. We must also see to it that there is no overlapping of teeth. The rays must be directed parallel to the mesial and distal surfaces. If the rays are misdirected to the mesial or to the distal, the shadows of the individual teeth will be partially superimposed, blotting out the proximal areas and often making it impossible to detect proximal caries.

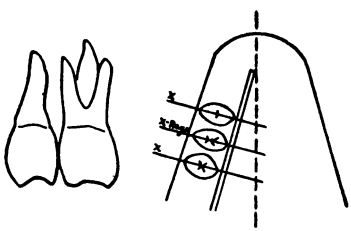

FIG. 59. Correct Horizontal Angle.

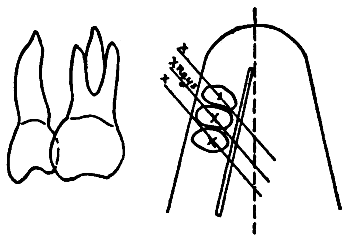

FIG. 60. Incorrect Horizontal Angle.

2. **Position of Patient and Tube.** In order to standardize our technique and to use definite average angles in projecting the rays, it is important that we always place the patient's head in the proper position. If we fail to do this, any scale of angles will be unreliable. The sagittal plane of the head and the occlusal plane of the teeth must bear a definite relation to the vertical and horizontal planes in which the x-ray tube is moved. The tube is moved in a horizontal plane from the sagittal plane and in a vertical plane from the occlusal plane.

In seating the patient the sagittal plane of the head must be perpendicular to the floor regardless of whether the head is tipped forward or back.

In other words the head cannot be inclined to one side or the other without seriously affecting the angulation. Moreover, the occlusal plane of the teeth must be parallel with the horizontal plane, which may be

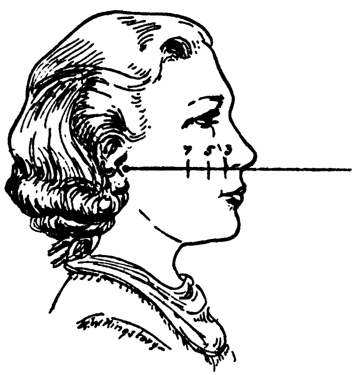

FIG. 61. Horizontal Plane.

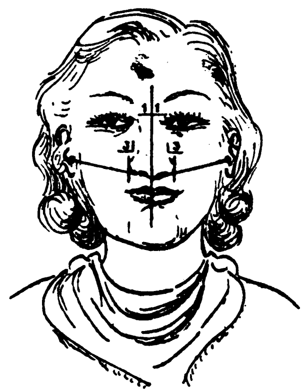

FIG. 62. Sagittal Plane.

regarded as the plane of the floor. If an imaginary line is taken from the ala of the nose to the tragus of the ear and the head is placed so this line is parallel to the floor, we find that the occlusal plane of the upper teeth is parallel to the floor. As it is necessary to have the mouth open while making intra-oral periapical exposures, the occlusal plane of the lower teeth would not be parallel to the floor while the head was in the above position. Hence to make exposures of the lower

teeth it is necessary to tilt the head backward until the occlusal plane of the lower teeth is parallel to the floor. This may be gaged by the eye with the aid of an imaginary line extending from the tragus of the ear to the corner of the mouth. There is also a spirit-level device on the market which may be used to make certain that the occlusal planes are horizontal.

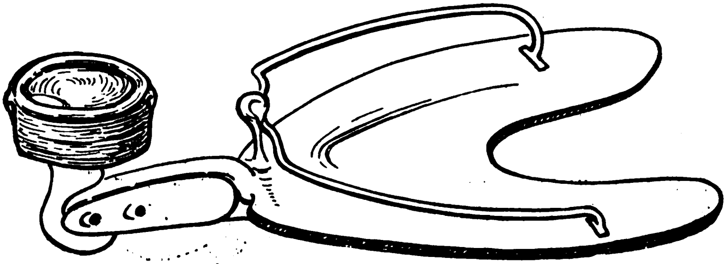

FIG. 63. Occlusal Plane Level.

If care is taken to position the patient correctly the operator need not actually go through the process of "bisecting the angle" in order to determine the correct vertical position of the tube nor is it necessary to compute the horizontal position in each case. It has been determined that in average mouths these angles are practically constant and by setting the tube at a certain vertical and horizontal angle for each area of the mouth uniform results may be obtained. The accepted angles for the various parts of the mouth are as follows:

	Degrees Horizontal plane	Degrees Vertical plane
Maxilla		
Molar region (7)	0	plus 30
Bicuspid region (5)	10	plus 40
Cuspid region (3)	45	plus 45
Incisor region (1)	90	plus 55
Mandible		
Molar region (7)	0	minus 5
Bicuspid region (5)	15	minus 10
Cuspid region (3)	45	minus 20
Incisor region (1)	90	minus 20

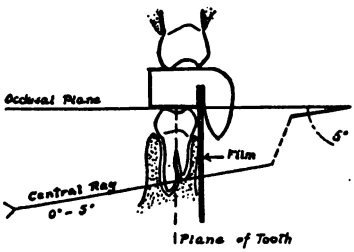

FIG. 64. Lower Molars.

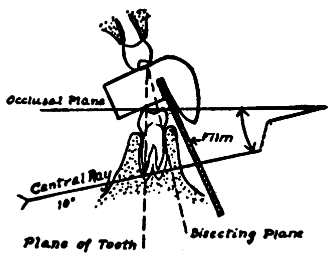

FIG. 65. Lower Bicuspids.

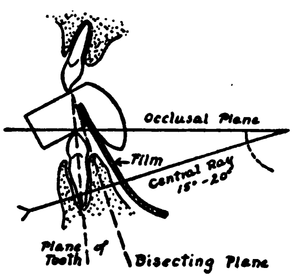

FIG. 66. Lower Cuspid.

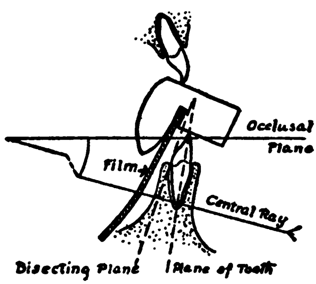

FIG. 67. Lower Incisors.

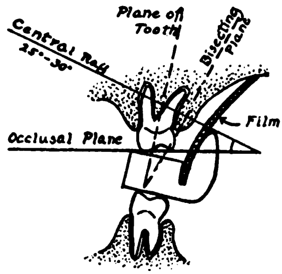

FIG. 68. Upper Molars.

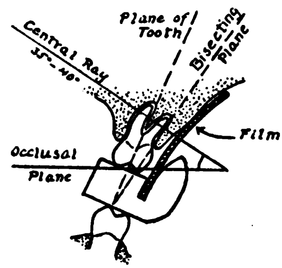

FIG. 69. Upper Bicuspids.

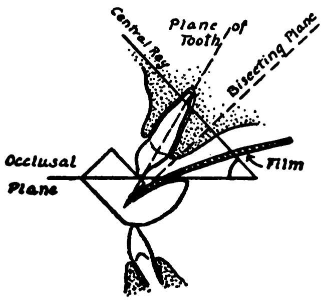

FIG. 70. Upper Cuspids.

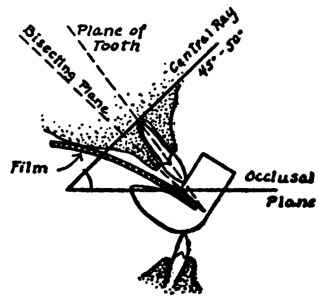

FIG. 71. Upper Incisors.

With the head correctly placed and the tube adjusted to the proper angle, it is still necessary to direct the rays at the proper points along the imaginary line. See Figs. 61 and 62. In exposing the upper incisors the rays will be directed through the nasal fossa at the median line. The point of entry for the rays when exposing the upper cuspids is on this imaginary line one-quarter inch distal to the ala of the nose. For the bicuspids the rays are directed at the intersection of this imaginary horizontal line and a perpendicular

line bisecting the eye. The upper first molar is located by dropping a perpendicular to the imaginary horizontal line from the outer angle produced by the intersection of the eyelids. The position for the second molar is one-half inch distal to that for the first molar. Determining the point of entry for the rays in exposing the lower teeth is comparatively simple because the operator can look into the mouth and line up his x-ray tube accordingly.

3. **Placing the Film.** It is desirable to follow a definite order in exposing the areas of the mouth. Failure to do this occasionally results in some areas being left out and other areas being exposed twice. Just what that order is to be is not important except that we should start out with the areas least likely to result in discomfort to the patient. Some people have a tendency to gag when the film is placed in position for the upper molar region. This is much less likely to occur, however, if we have acquired the patient's confidence by exposing the lower teeth first.

A. The bite block method. The film may be inserted in a small wooden bite block or the patient may hold it in position by the thumb and forefinger method. Wood block film holders can be secured from the supply houses. The film is inserted in the slot of the block with the sensitive side of the film toward the biting surface as illustrated. The other side of the film is backed with a thin piece of lead which would obstruct the passage of the rays. The wood block with

film inserted should be placed in position and the patient instructed to bite on it and not to move during the exposure. Needless manipulation of the film in the mouth is apt to cause the patient to gag. However, in placing the film for exposure of the upper

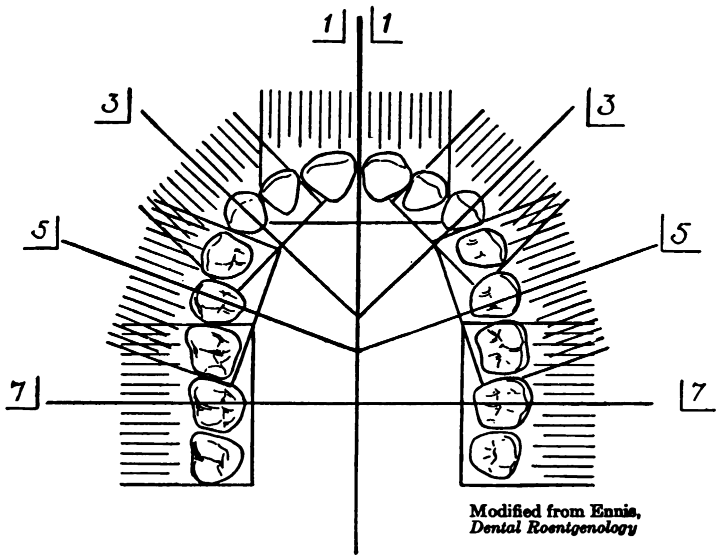

FIG. 72. Horizontal Angles. Rays Directed Perpendicular to Mean Tangents of Teeth.

molars it is frequently better to place the block in the bicuspid region and slide it back to the molar region. In placing the film for the lower teeth, the film is inserted on a slant toward the base of the tongue and is then drawn up and against the teeth and gums. When using the bite block it is comparatively easy to have the edge of the film parallel to the occlusal

surface and to maintain a uniform alinement of the teeth which adds greatly to the appearance of a set of negatives.

B. Digital Method. If the patient is to hold the film in the mouth, it is necessary to place the film carefully and then place the patient's finger or thumb where he is to hold it and to demonstrate the amount of pressure to be applied in order to hold the film from slipping and yet not to produce unnecessary bending. In exposing the teeth of the upper jaw the film is held with the thumb, and in the lower jaw with the first finger. Occasionally the shape of the arch or the patient's inability to open the mouth sufficiently prevents using the bite block or even the digital method of holding the film in position. In this event the patient holds the film between the incisal edges of the teeth. In making an exposure of the upper anterior teeth in this way, the tube is placed at a vertical angle of 65°. Both the regular size and the occlusal size film are used for this purpose.

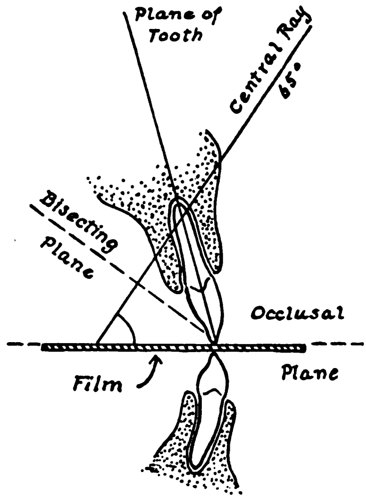

FIG. 73. Position and Angles for Occlusal Film. Upper Central Region.

4. Localizing Buried Roots.

The x-ray negatives show only two dimensions, length and breadth. By making more than one exposure and shifting the horizontal angle it is possible to secure information about the buccolingual position of teeth or portions of teeth that are embedded in the jaw. On taking a second exposure at a slightly different horizontal angle, if the shadow of the embedded object appears to have moved in the same direction in which the tube was moved (mesial or distal), then the object lies lingual to the adjacent teeth. If the shadow of the object in question appears to have moved in the opposite direction to that in which the tube was moved (mesial or distal), the object lies to the labial or buccal of the adjacent teeth.

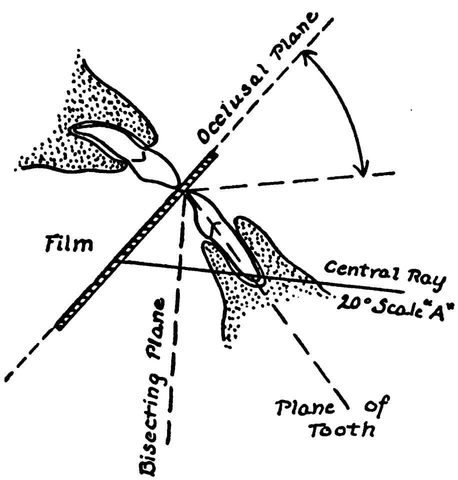

FIG. 74. Position and Angles for Occlusal Film. Lower Central Region.

5. Unerupted or Impacted Teeth. Occlusal Examination. The occlusal films are a great help in detecting the presence of impacted or unerupted teeth, foreign

bodies, fractures, and stones in the salivary duct. The occlusal films are also very helpful in making a survey of the jaw as a whole.

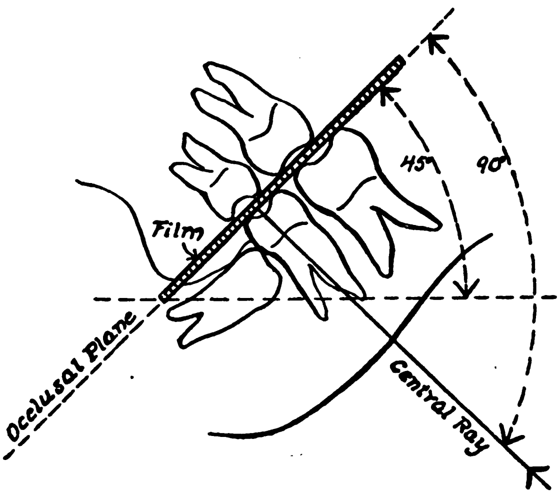

FIG. 75. Position and Angles for Occlusal Film. Lower Third Molar Region.

6. **Interproximal Examination.** The bite wing films were designed by Dr. Raper to assist in detecting incipient conditions before more serious consequences develop. They are used to supplement the usual periapical exposures and the clinical instrumentation in detecting interproximal cavities, overhanging fillings, pulp stones, and changes in bone density due to periodontoclasia.

From five to seven films are necessary to make a complete interproximal examination. The crowns of

both the upper and lower teeth are shown on the same film. The head position is the same as for the periapical exposures but the angle is plus 8 degrees for

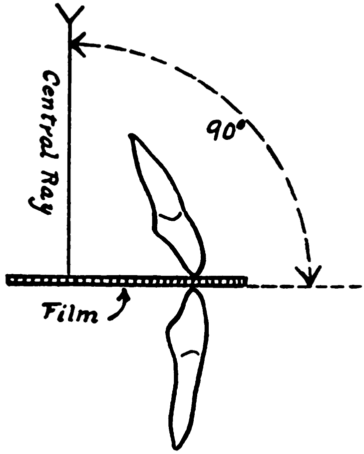

FIG. 76. Upper Occlusal View.

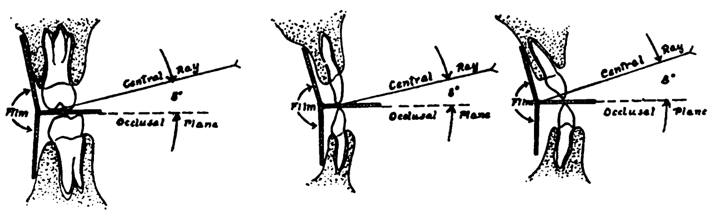

FIG. 77. Posterior Region. Cuspid Region. Incisor Region. Interproximal Examination.

all exposures. The patient holds the film in place against the lingual surface of the crowns by biting on the tab or wing.

7. **Exposure Time.** The dental x-ray units of today are so designed that there is very little left to guess-

work, and it is reasonably certain that if the operator follows the directions for positioning the patient, placing the film, directing and timing the rays, and processing the film, he will produce a negative that is capable of intelligent interpretation. The exposure time will vary slightly with different apparatus, some having greater penetration than others. Also with the same apparatus and the same target film distance the exposure time will vary with the age of the patient (the density being less in a child, with the density of the area exposed and with the type of film used. The emulsion on some films reacts much more quickly to the rays than that on others. Variations in the density, frequently have diagnostic significance, however, and should not be obliterated by altering the exposure or the developing time. The normal range of exposure time for a given machine may vary from one to nine seconds for intra oral negatives according to the age of the patient, the speed of the film used, and the area exposed.

8. **Extra Oral Technique.** Shadows are always sharper and less distorted if the object is close to the screen. The intra-oral method of taking radiographs is usually preferred to the extra-oral methods as it permits placing the film close to the object and thus produces more distinct results, showing greater detail. However, there are conditions difficult or impossible to show by the intra-oral method and it is necessary to resort to the extra-oral method. Fractures and third

molar impactions are frequently revealed much better on a large film than on one placed inside the mouth. Inability to open the mouth wide enough for the insertion of the small film is often a cause for using the extra oral technique. Children's mouths are frequently too small to properly accommodate the intra oral film. In case of extensive pathology the area is sometimes greater than can be shown on a single film. Here the larger film will give a view of the entire region.

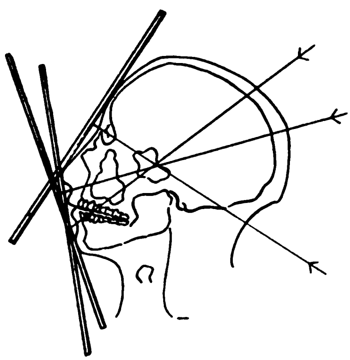

FIG. 78. Angle for Frontal and Maxillary Sinuses

A. Correct Angles for Lateral Examination of the Head. As in intra-oral technique it is necessary to establish certain relations between the position of the head and the film and the direction of the rays. Some find it easier to make these adjustments if the patient is lying down while others secure equally good results with the patient erect or inclined in the desired position while sitting in the dental chair. Which method one uses will depend upon choice and the available equipment. The rays should be directed perpendicularly to the plane of the film.

B. Screens. In exposing this larger area it is necessary to have the target of the tube farther from the film and the rays are obliged to penetrate a greater bulk of

tissue. This means a longer exposure. However, this may be offset by using faster films and by the use of intensifying screens. Other factors being constant, better results will be obtained if screens are not used. It is often not advisable, however, to subject the patient to the longer exposure which the lack of screens would necessitate. Possible movement of the patient during the longer exposure may be a greater factor than the difference in the quality of the result when screens are used. Distórtion is greater if the target of the tube is close to the head. It is therefore advisable to have apparatus with sufficient penetrating power that the tube may be some distance from the head during exposure.

Questions.

1. Is the x-ray negative a shadow picture?
2. What is the ideal relationship between source of radiation, object, and screen, in order to produce a shadow having the least distortion.
3. Can the ideal relationship of source of radiation, plane of the film, and plane of the tooth be realized in making x-ray negatives of the teeth?
4. What do we mean by vertical angle, horizontal angle, occlusal plane, and sagittal plane?
5. What is meant by the term "bisecting the angle"?
6. Why is the position of the patient's head important?
7. How would you manage to secure views of the individual roots of multi-rooted teeth?
8. How can you tell whether an embedded object or root is lying lingually or buccally to adjacent teeth?
9. When are occlusal films used?
10. Why do we take bite wing exposures, and what is the vertical angle used?

Chapter X

DANGERS AND PRECAUTIONS

The manufacturers have steadily improved, simplified, and made more fool-proof their x-ray apparatus. Hence the present day dental x-ray equipment is not only a highly efficient unit, but is so safeguarded that there is little excuse for the operator who injures himself or his patients. The apparatus is delicate and is still dangerous, however, and there is no place for the careless operator.

The dangers one needs to guard against are:

1. **Electrical Shocks or Burns.** There are several dental units now on the market which have the high tension circuit so well guarded that there is no danger of the patient or the operator coming in contact with the high voltage. In one type of unit this is accomplished by enclosing the step up transformer and the tube in the same oil filled metal tank, a window of radiopaque material being provided to allow the x-rays to leave the container so that they may be used.

Another type of unit provides this shock-proof feature by grounding the transformer in the center and enclosing the tube in a framework which provides space

insulation for each side of the circuit. Each type has its particular virtues.

Some of the dental equipment has one exposed high tension line with which the operator and patient must not come in contact. Many minor accidents have happened where the high tension lines are exposed. Fatal results may follow, however, and in any event the nervous shock may be serious. It is wise to keep all high tension lines at least twice as far from the patient or operator as the spark gap through which the voltage used might jump. Thus if a voltage capable of jumping three inches is used, at least six inches should be maintained between any part of the line and an individual. In event resuscitation is necessary following an electric shock, the prone pressure method of artificial respiration (Schaefer method) is advised.

2. **X-ray Burn.** A burn produced by the action of the x-rays on living tissue is a far more insidious danger than that of electrical shock or burn. The x-ray burn is not felt or recognized until a chronic condition is produced which is often difficult or impossible to eliminate. The effect of the rays is cumulative; that is, an exposure today might produce no ill effect, but the same exposure repeated daily would ultimately produce undesirable results. The known effects to be guarded against are (1) burns on the superficial tissues; (2) injury to internal organs; and (3) changes in the blood.

The danger of receiving an x-ray burn is now much

less than it was with the early x-ray apparatus. The dental units are particularly well guarded in this respect, and in an office where the exposures are made only occasionally, the danger is nil. However, if an operator deliberately exposes himself by standing directly in the path of the rays or makes a practice of holding the film in the patient's mouth, he is courting disaster regardless of the type of equipment he uses.

During the early years of x-ray work operators subjected themselves unknowingly to this danger. The exposures were long, varying from a number of minutes to an hour or more. As would be expected, it was observed that certain undesirable results followed these excessive exposures to the x-rays. Loss of hair (alopecia) and a dermatitis resembling sunburn were reported. One of Edison's assistants became the first known victim, dying from what was called x-ray cancer. By improvement in apparatus and the use of intensifying screens the exposure time was greatly reduced. The operators worked behind lead screens, or with lead aprons and gloves, and the room housing the apparatus was lined with sheet lead. Tubes came to have lead glass shields and more recently lead jackets to absorb stray radiation.

3. **Fire Hazard.** The unfortunate Cleveland hospital fire of a few years ago which resulted in the death of over one hundred people was due to the fumes given off from burning celluloid x-ray negatives in the basement store room. This catastrophe, however,

served to focus attention on the danger connected with the handling of large quantities of highly inflammable celluloid. In dentistry we have to think not only of the inflammability of the films but also of the celluloid frames in which the films are mounted for study. Though some people had been working to substitute aceto cellulose, which burns about the same as an equal amount of paper, for the highly inflammable nitro cellulose, their efforts met with speedy results following the Cleveland fire and there is no longer any need for using the inflammable material. However, one should be sure to specify aceto cellulose or "safety film" when ordering.

4. **Infection.** The danger from infection arises from the fact that many think of the x-ray machine as a piece of furniture rather than as an instrument as far as sterilization is concerned. One permits the machine to acquire a coating of bacteria which is a real danger to the patient. In making intra-oral exposures the fingers of the operator come in contact with the patient's mouth and with certain parts of the x-ray machine. After taking care of the patient, he washes his hands and later makes exposures of another patient. In handling the machine and then placing his fingers in the patient's mouth he transmits the bacteria of the first patient to the mouth of the second. Washing his hands has been of no avail. Some operators wear rubber gloves as a precaution. The rubber gloves may serve to protect the operator, but they fail to protect

the patient unless the parts of the machine which are handled are cleaned between patients.

Questions.

1. What are the dangers which one should guard against in x-ray work?
2. Why did the early operators of x-ray apparatus not exercise greater care?
3. What additional equipment has cut the exposure time?
4. What changes in the construction of x-ray machines has greatly lessened some of the dangers?
5. What is the difference between nitro- and aceto-cellulose?
6. How would you attempt to revive a person who had received a severe electric shock?
7. Is there any possibility of spreading infection from one patient to another by means of the x-ray apparatus?
8. What is the purpose of lead glass and lead screens in x-ray work?
9. What do we mean when we say the effect of the x-ray is cumulative?
10. How far should one keep from the high tension line of an x-ray machine which has exposed wiring?

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